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GROUND WATER AND SNOW AS FACTORS AFFECTING THE SEASONAL DISTRIBUTION OF POCKET GOPHERS, *THOMOMYS MONTICOLA*

BY LLOYD G. INGLES

The effect of ground water and snow on the seasonal distribution of the mountain pocket gopher (*Thomomys monticola*) has received the casual attention of but few observers. Grinnell (1923) pointed out how he believed the animal makes use of snow in acquiring food in winter. He later (1933) noted that this species of pocket gopher frequents the margins of meadows and implied that the lowest and wettest parts of a meadow are generally not used by the animals. Grinnell and Storer (1924) described and pictured some of the winter work of this pocket gopher with particular reference to its activity in snow. Howell (1924) made general observations on the habitats of the species with respect to drainage and to soil moisture. Marshall (1941) studied *Thomomys talpoides* and made certain general observations on the winter behavior including an account of an animal actually burrowing in the snow. Hall (1946) pointed out the importance of snow in enabling *Thomomys monticola* to reach new territory over what would otherwise be dangerous terrain for the animals to traverse in the summer.

In order to study more precisely what effect ground water, including snow, has on this species of pocket gopher, 35 animals were live trapped, marked, and their movements were studied in all seasons of the year between April 1947 and November 1948. Two stations located in two small meadows in the Sierra Nevadas near Huntington Lake, Fresno County, California, were selected for this study. It must be understood that this species of *Thomomys* does not require water to drink. They are frequently found on dry granitic slopes in late summer many hundreds of yards from the nearest surface water. Apparently their water requirements are all met by the food they eat.

Station B is on the summer campus of the Fresno State College at an altitude of 7000 feet (Pl. I, upper). The area of the station is 1.4 acres, and comprises most of a meadow which is entirely surrounded by lodgepole pines. Along its northern edge is a steep slope which rises about twenty-five feet above the rest of the area. On this grassy and sedge-covered slope is a spring which flows about six months each year. In late spring the melting snow keeps the lower part of the station covered with water for at least two months. In summer there is no surface

water on the area and most of it becomes too dry to support grass or sedges except in small patches. Certain liliaceous plants, however, are common. In the open meadow the soil temperature taken four inches below the surface ranges from 30°C on the first of September to .5°C under two inches of frozen earth on the first of February. The meadow has been undisturbed except for a foot path, which is used for about six weeks each summer.

Thirty-one pocket gophers were marked on this station over a period of six months and fourteen of them repeated in the traps enough times to enable me to map their home ranges. Because of the small size of the meadow all but three of the animals had home ranges with burrow systems extending up to the woods on the higher ground at the edges of the open meadow.

Station C is a small area comprising one-half acre at the upper end of a fifteen-acre meadow which is the source of a small but permanent stream (Pl. I, lower). This station was chosen because it represents an "island" of grassy vegetation almost entirely surrounded by very wet, boggy soil which in winter is frozen. The whole meadow is composed of a series of these small grassy "islands" or benches, and is surrounded by lodgepole pines and red firs. Station C was occupied by four adult pocket gophers in the summer and autumn of 1947, all of which were nearly isolated from the woods by earth which was too wet for burrowing. These animals were marked and the home range of each was established by repeated catches.

In order to measure the water table, a line of holes was drilled on the upper part of the meadow which also crossed station C (Fig. 1). The water table was then studied with reference to the burrowing activities of the animals. This meadow is grazed by cattle for a part of each summer.

The pocket gophers on these two stations respond to the onset of winter quite differently. This was evident by both their surface activity and by trapping records. After the first snow fall, about the middle of September, each year, the animals on station B began moving to higher ground under the trees at the edge of the meadow. The ground in the open meadow soon froze from two to four inches deep and remained frozen until the middle of May. During this period there was no evidence of gopher work in the meadow except where the animals had gone out onto it through the snow from their nests under the trees. Several of the marked animals were trapped under the trees in the loose humus-filled soil. The soil beneath the trees does not get wet, does not freeze, and in it a limited amount of surface workings are continued throughout the winter. In each case the winter burrow system under the trees was an extension of the system that had been occupied by a particular animal in the open meadow the previous summer. Three animals whose ranges were from 80 to 150 feet away from the margin of the meadow remained on their summer ranges all winter. They came above the frozen ground and established nests in the snow. These snow nests were spherical in shape and were about ten inches in diameter. They were constructed of fine grasses and the husks of a small corm (*Triteleia ixioides*) which the animal uses for food. These snow nests are not different in structure from one which was found eighteen inches under the loose soil at the base of a large lodge-pole pine at the margin of the meadow. From these snow nests the animals established a network

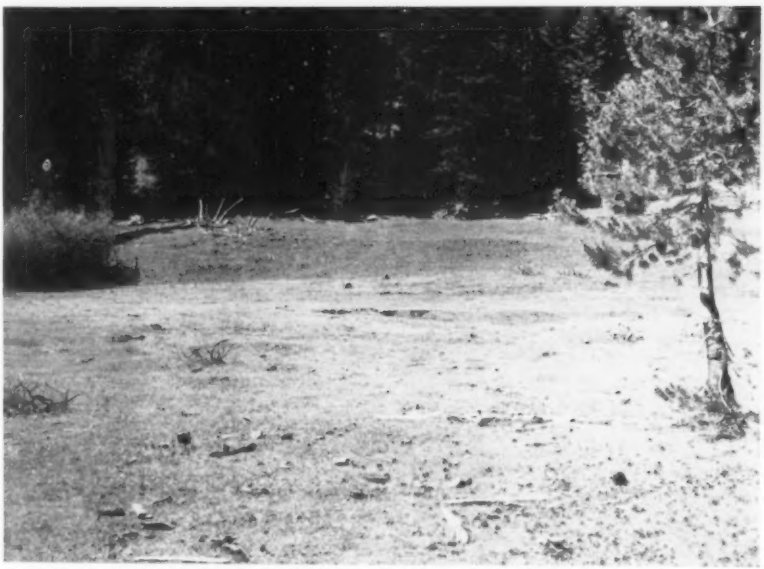

PLATE I

UPPER: Station B (late summer). Pocket gophers work over entire area in summer. In late spring the area is largely covered with water.

LOWER: Station C (late summer). This station occupies the grassy bench in the foreground. Here the water table varies from one to seven feet according to the season. The station is almost entirely surrounded by wet boggy soil on the slopes.

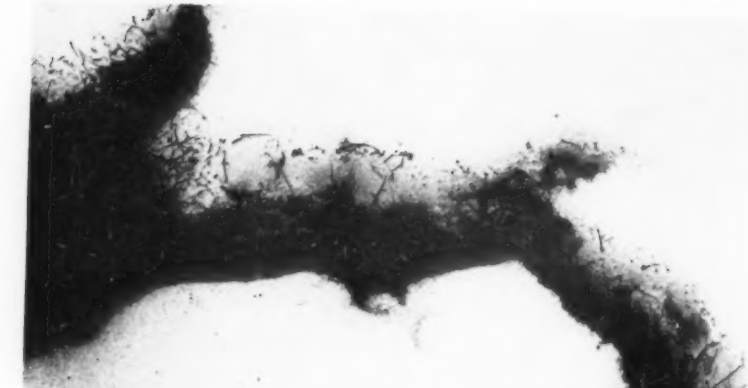

PLATE II

UPPER: A snow burrow plugged with ends of grass blades
LOWER: Station C. A tunnel dug just under the snow over a grassy meadow

of tunnels which were generally dug just over the surface of the frozen ground where they foraged for their food of grass stems (Pl. II, lower). Frequently these burrows, dug up through the snow, would parallel the surface of the ground as much as four feet above it for a rod or more. Occasionally they would be plugged with the dry ends of grasses and corn husks to form "cores" up to three feet in length (Pl. II, upper). One of the snow nests was located on the top of a stump in an area on which there was no grass or other edible plants on the surface. Here the underground connection was maintained, and it seems likely the animal had access to an underground cache of food. Just outside of each snow nest was a

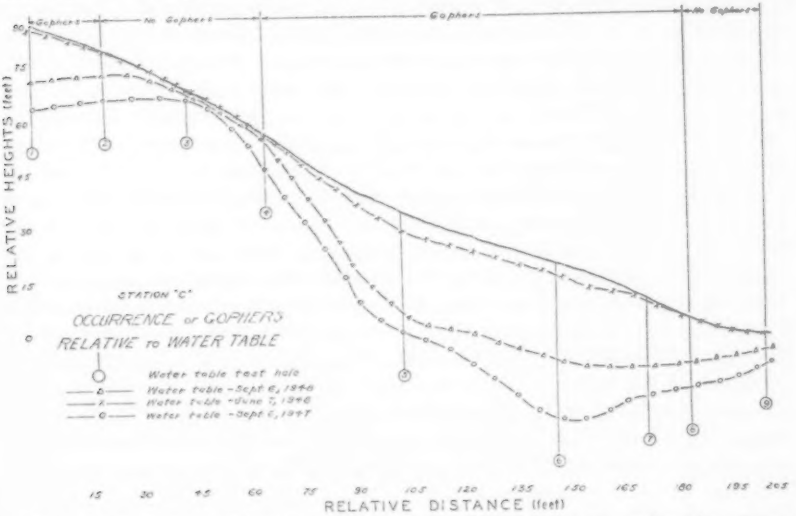

FIG. 1.—Profile map of Station C, showing occurrence of pocket gophers in summer in relation to the water table. Scale of water-table depths is 1:90.

"privy" consisting of hundreds of oblong fecal pellets. Similar snow nests, constructed by *Thomomys fossor*, were found by Warren (1937).

When the snow melted down to the nests during the spring thaw the pocket gophers were compelled to abandon them. They could not enter the water-soaked earth and at least two of them moved to higher ground over 100 feet away by burrowing through the remaining snow banks. In so doing one of the animals had extended its burrow along a deep drift four feet above the ground and had crossed a rapidly flowing small stream three times. Other similar burrows, observed in other meadows after the start of the spring thaw, doubtless represent the routes by which the animals escaped to safety on higher ground. Linsdale (1938) believed it characteristic for individuals of *Thomomys bottae fumosa* in Nevada to remain with their homes after being forced out by flood-water rather than start out in search of more suitable sites. This was apparently not the case with *Thomomys monticola*; they abandoned their burrow systems when they became too wet.

The four marked pocket gophers on station C remained there until the deep snows had covered it. There was considerable activity under and through the snow throughout the winter, and it seems not unlikely that the animals continued to stay until the spring thaw brought the water table close to the surface of the ground (Fig. 1). On June 1, 1948, two snow burrows were found leading from the station up the remaining drifts to higher ground about 150 feet away. When the snow had completely melted two weeks later only two pocket gophers occupied the area and only one of these was marked. This animal had changed its burrow system a distance of 60 feet from the one it had occupied during the previous summer. This burrow system was on one of the two remaining areas where the water table was still twelve inches below the surface. The other area, adjacent to the first, was occupied by the unmarked pocket gopher. This latter area had been occupied by a marked individual during the previous summer. It is possible that the marked animal which was still on the area never left the station during the winter or even during the spring thaw although a snow nest could not be found. In summer this species of pocket gopher will extend its exploratory burrows out over muddy ground just above a shallow water table, but its permanent burrows including a nest were never found in soil with the water table less than 4.3 feet from the surface. Whether the marked animal had remained on the area or had recently returned does not alter the fact that its entire burrow system was at that time over a twelve-inch water table. Neither of these two pocket gophers was on the station by August 16 when the water table was a little more than four feet from the surface (Fig. 1). The "unmarked" animal (marked in June) was taken at that time 150 feet west on the relatively dry hillside bordering the meadow. In order to reach its new range it had to cross over the surface on the wet mossy slopes. Apparently these two pocket gophers left the station because the water table did not recede fast enough for them to establish permanent summer burrow systems.

By the middle of August the station was connected to the hillside east of the meadow by a narrow corridor of moist but burrowable soil. By the first week in September an unmarked pocket gopher had entered the station by this corridor leaving a line of nineteen surface mounds over a distance of seventy feet which by the first of October had been extended nearly 100 feet out onto the station. An adult female was taken in this burrow system. About the same time a fresh mound appeared far out on the station without any obvious connection to the woods at the margin of the meadow. A half-grown juvenile, which had apparently just moved onto the area by moving over the surrounding wet surface, was taken in this burrow.

It is obvious that both juveniles and adults may move from an area that is too wet to a more suitable location by traveling over the surface. It is also true that a pocket gopher may reach a suitable area several yards away by burrowing through the soil provided the water table is low enough to permit it to do so. The occupancy of suitable areas, however, seems to be largely determined by chance. At both stations there were home-range areas occupied in 1947 that were unoccupied in 1948, and new areas were occupied in 1948 that had no animals on

them in 1947. Ecological barriers, usually a strip of wet soggy earth only a few feet wide, frequently prevented the animals from reaching suitable terrain.

There were considerably more snow-workings on station C than there were on station B in the winter months. The animals on station C had to depend to a great extent on grass stems for food because the ground, being moist, froze to a depth of about four inches before the heavy snows fell. The dry ends of the grass stems were not eaten, but were solidly plugged into the snow burrows. These grass-plugged tunnels were especially numerous in the burrows that were dug just beneath the snow (Pl. II). Also exposed, were a number of cores of mineral earth as the snow began to melt. These earthen cores were generally the result of plugging the tunnels dug along the surface of the earth, but not infrequently they extended up into the snow as far as four feet above the ground. The lengths of the cores and the numbers of them vary with the length of time the snow covers the ground. The cores are usually 10–20 feet long. At Kaiser Pass (elevation 9300 feet), where the snow covers the ground about six weeks longer than it does at Huntington Lake, one measured thirty-nine feet in length without the lateral branches. Tryon (1947), working with *Thomomys talpoides* in Montana, believed these cores were most abundant in meadows where the early snow fall prevented the ground from freezing. Such was not the case here where the early snow falls melted, saturated the ground with water, then froze down to four inches.

No evidence was found to indicate that the animals ever feed above the surface of the ground, on twigs of shrubs, as suggested by Grinnell (1923). Neither did trapping records give any indication of prolonged periods of inactivity as suggested by Howell (1924).

In late spring after the surface water had disappeared from station B the pocket gophers that had wintered in the timber at the edge of the meadow began to move out onto the meadow again. Sometimes these exploratory burrows were actually made through mud which was found to be 33 per cent water by weight. In general the animals occupied the same areas that were used for home ranges the previous summer. However, as the seasons advanced the burrow systems shifted to include other adjacent areas not already occupied. In a few cases these included parts of areas previously occupied by animals that did not return. In summer, no activity was observed in the winter home range.

Those animals that had lived farther out on the meadow did not find their ways back to their original home ranges. Only one of the pocket gophers that lived on station C during the summer of 1947 appeared on the meadow the next summer and, as stated above, this animal occupied an entirely different range the second summer; it had left the area by the middle of August. All the other animals on station C were new to the area.

SUMMARY AND CONCLUSIONS

Thirty-five pocket gophers (*Thomomys monticola*) living on two small meadows in the Sierra Nevadas were marked and studied for twenty months.

In summer the animals live in burrows on ground where the water table is deeper than 4.3 feet. They will explore areas where the water table comes within one-half foot of the surface when deeper drier soil is nearby for a nest location.

As winter approaches those animals living at the margins of a meadow move underground onto higher ground beneath the trees. Here the humus soil and better drainage prevents the soil from freezing and a limited amount of surface working is found even in winter. As the surface water disappears in late spring these animals move out onto the open meadow and occupy approximately the same home ranges they had occupied the previous summer, but ultimately may move onto contiguous unoccupied areas.

Pocket gophers living farther out away from the margins of the meadow remain there through the winter until spring when they are compelled to seek higher ground to avoid the rising water table and surface water. These animals get their food largely from the surface of the ground by burrowing just beneath the snow. Sometimes their nests are actually made off the ground in the snow. None of the pocket gophers found their ways back to their previous home ranges although one did appear the second summer on the same station.

Ecological barriers, such as very narrow strips of wet soggy soil, frequently prevent the animals from attaining suitable home range sites.

This species occasionally makes tunnels over 100 feet long through the snow. Sometimes cores of dry grass, earth, and other waste material are found in these snow tunnels. The length of the cores varies roughly with the length of time the snow is on the ground. One measured thirty-nine feet long without its lateral branches.

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Fresno State College, Fresno, California. Received November 3, 1948.

A POPULATION STUDY OF HOUSE MICE (*MUS MUSCULUS*) FOLLOWING A PERIOD OF LOCAL ABUNDANCE

By Francis C. Evans

Introduction.—It is well known that populations of animals and plants are not static structures, but are dynamic, constantly altering in size. Some of these alterations are irregular fluctuations; others have been shown to be cyclic in character, recurring periodically. For a few species, the rate of population growth under laboratory-controlled conditions has been worked out in considerable detail, but similar knowledge of populations in their native environments is still scarce.

The factors affecting the growth of natural populations likewise are obscure and poorly understood. The apparent correlation of certain population cycles with sunspot cycles has long been noted and its significance disputed. The abundance or scarcity of food, the extent of predation, and the incidence of disease have often been cited or suggested as controlling factors. Much talk about density-dependent and density-independent factors is frankly speculative. It is encouraging that recent students of populations have begun to analyze more carefully the structure of populations at various stages of their development and to investigate their reproductive physiology. We need to know more about sex ratios, age classes, breeding portions of the population, numbers and sizes of litters, extent of immigration and emigration, and similar data before we can intelligently appraise the causes of population change.

Studies of house mouse (*Mus musculus*) populations in non-laboratory environments are few. An excellent paper by Laurie (1946) on the reproduction of house mice from four different types of natural (though man-made) habitat is based on extensive data from killed specimens. Southern and Laurie (1946) describe populations of house mice living in corn ricks, from complete censuses or samples likewise permanently removed from their environments, and refer to the most important previous studies of house mouse ecology. Baker (1946) employed live-trapping and marking techniques to study wild and commensal house mice on Guam.

During the winter of 1941–42 opportunity came to study a population of house mice on the campus of the University of California College of Agriculture at Davis (Evans and Storer, 1944). Local complaints of mouse abundance were frequent in the preceding autumn, and early in January, 1942, there were reports of large numbers of mice in the Agronomy Seedhouse, a small building used to store experimental seeds and grains. Investigation confirmed these reports, as shown in the following field notes:

"Ten mouse traps, of the ordinary 'break-back' variety and four 'Delusion' (multiple catch) type live traps were set at about five P.M. . . . Within ten minutes of setting, five traps had sprung, each catching one mouse. It is impossible to estimate the numbers that must be present, but they were running all over the room, and squeaks and rustles could be heard on all sides." (Jan. 7).

"One of the 'Delusion' traps had 12 mice in it . . . " (Jan. 8). The available

evidence pointed to a small localized "mass outbreak" similar to that at Davis in 1926 (Storer, 1931) and to larger irruptions at Buena Vista Lake (Hall, 1927) and in Australia and Russia (Elton, 1942). The population here described was much smaller than most of the reported outbreaks, but the observations may be of value because of the extended period of time through which the population was followed and during which no effort was made to terminate the irruption artificially or otherwise to disturb the natural course of events.

The field work for this study was done while I was Junior Zoologist in the Agricultural Experiment Station at Davis; the material was analyzed and written up at the Laboratory of Vertebrate Biology, University of Michigan, where I am now stationed. I am greatly indebted to Professor B. A. Madson, Head of the

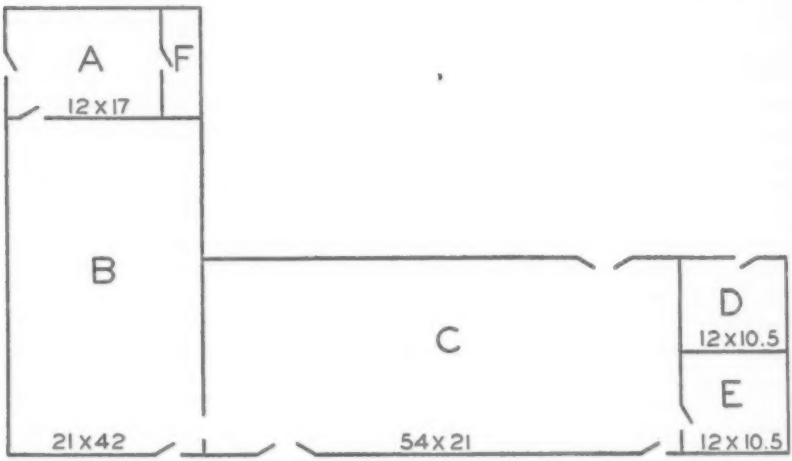

FIG. 1.—Floor plan of Agronomy seedhouse, University of California, Davis. A, office; B, grain storage room where trapping was done; C, equipment and machinery room; D, grass seed storage room; E, tool room; F, toilet.

Department of Agronomy at Davis, who permitted use of the Seedhouse to make the study; to Mr. E. E. Horn, U. S. Fish and Wildlife Service, who generously lent some of the traps used; to Miss Nancy Matthews for assistance with the field work; to W. G. Hillard for a floor plan of the Seedhouse; to Mr. John A King for drawing Figure 1; and to Dr. T. I. Storer and Dr. L. R. Dice for advice in the preparation of the manuscript.

Program and techniques.—On January 7, 1942, a live-trapping program was initiated in one room of the Seedhouse (Fig. 1,B). Seeds and grains were stored here in metal containers with lids, but small quantities became scattered on the floor and tables in handling the materials, thus affording a limited food supply for the mice. The room measured twenty-one by forty-two feet, and all trapping within the building was done here. Adjacent parts of the building housed several farm machines, some alfalfa, and other supplies. Additional traps were placed

outside the building, within fifty feet, at sites likely to afford shelter for the mice. Both indoor and outdoor trapping was fairly continuous throughout 1942, with varying numbers of traps for different periods of time (Table 1). Indoors, the traps included some of the 'Delusion' multiple-catch type and some metal modified 'Sherman' type traps which normally caught but one individual at a time; outdoors, only the metal traps were used. Traps were placed 'strategically' where capture was thought most likely; indoor traps were set on tables and shelves as well as on the floor. Once set, a trap was continued at the same site until removed at the end of a trapping period; in practice, the indoor trap positions, except for one or two relocations, remained unchanged throughout the study. Early in the work traps were tended twice a day; later, when few mice were taken, once a day was considered sufficient. Trapping was discontinued on December 24, 1942.

When first caught, individual mice were marked by toe-clipping, sexed and weighed, observed for breeding condition and pelage, and released at the site of capture. A balance weighing to 0.1 gram was kept where the trapping was done, and each mouse was placed in a small container or wire cage for weighing. Recaptures were frequently weighed and examined for reproductive condition to follow the development of each individual.

Reaction to traps.—It is often assumed that such trapping provides random samples of the population and that all individuals are equally "trappable." Laurie (1946) found that trapping was selective; an unduly large number of the small mice failed to be caught. The lightest weight recorded in the Seedhouse population was 9.5 grams, although mice of 5 to 7 grams were taken elsewhere on the campus. This study also revealed striking differences in the frequency of capture. A few mice were regular repeaters, returning to the traps day after day for periods as long as 49 days. Such individuals were generally caught in the same or adjacent traps. Some mice would, upon release, run directly to another (often not adjacent) trap and enter it if open; in this way they were taken two or even three times on the same day. Their behavior suggested that the traps were actively sought as desirable places for shelter. In contrast, many other individuals were recaptured only after long intervals; at least thirty mice had intervals of thirty days or more between captures, thirteen of which exceeded fifty days, the maximum interval being eighty days. Still others were never recaptured; of the 224 marked and released, fifty-nine were not taken after their initial capture. These may have moved permanently out of trapping range, or they may have been present and refused to enter traps. It is clear, however, that a wide range in behavior existed; hence the data must be interpreted cautiously. Careful study of the records failed to show that these differences were associated with differences in age or sex. The factors making for "trap acceptance" are not understood, and extensive investigation of this problem is desirable before trapping can be considered a thoroughly satisfactory technique for population studies.

THE INDOOR POPULATION

Population trends.—In all, 235 house mice were caught in the one room of the Seedhouse, but not all of them were present throughout the period of study. This

total has been broken down to show the number of unmarked mice captured, the number of marked plus unmarked mice captured, and the number known to be alive (by subsequent recapture) for each month of 1942 (Table 2). The exact number of trapping units varied from month to month (Table 1), but was of the same order of magnitude except for the summer and early fall; the less extensive trapping at these latter times seemed sufficient to take any mice then present. It must be borne in mind that the trapping was confined to a single room which could be easily entered from adjacent parts of the building or even from the outside; therefore, the population of the room at any given time presumably represented only a part of that at large. This part is referred to as the indoor population and during the year probably came to include most of the house mice of the entire building. Evidence as to egress and ingress will be presented later.

The population of this room seemed at or beyond its peak by January, 1942. The rapid and continued decline of unmarked mice indicates a fairly complete take of the population in the first few months of the year and a complete lack of additions to it during the summer and early fall, suggesting a failure of any existing individuals to breed or to immigrate from nearby territory. Decrease occurred also in the total number of mice captured each month and in the total number known to have been alive. No mice were taken in the Seedhouse from May through October, although they were still present in other buildings, and none of the individuals caught in November or December was known to have been present in the earlier indoor population. This is fairly convincing evidence that this population suffered a "crash" to the point of extinction, and the partial "recovery" in the late fall is attributed to the immigration of individuals from outdoors. The indoor population of the winter of 1942–43 began to develop in November, but there was no concentration like that of the previous winter.

The decrease in numbers caught each month from January to May appeared to be linear, involving a net loss of thirty-one to thirty-six individuals per month. This means that the *rate of decrease* rose sharply as the population declined. Comparing the number taken in a given month with that for the month preceding, the rates of decrease were as follows: February, 26 per cent; March, 31 per cent; April, 46 per cent; May, 86 per cent; June, 100 per cent. The acceleration in rate of decrease is even more abrupt if based on the numbers known to be alive. "Crash" indications apparently included a mounting proportion of losses from the population.

Estimated population.—The proportional method of estimating populations from trapped samples—often called the 'Lincoln Index'—is widely used, partly because of its essential simplicity and partly for lack of anything better. In consequence, it has gained rather general acceptance as 'correct.' Briefly, the method assumes that the number of individuals marked and released in period A represents the same fraction of the total population of period A (i.e. the estimated population) as the number of recaptures in period B does of the total number of individuals caught in period B. This formula is based on two fundamental premises: (1) the samples collected in the two periods are equally random, and (2) there has been no change in the ratio of marked to unmarked individuals

during the interval between samples. Premise 1 requires that trapping procedures in the two periods be identical, that all individuals remain equally trappable from

TABLE 1.—*Trapping schedule for study of house mice at Davis, California. Dates given are inclusive*

TRAPPING DATES	NUMBER OF TRAPS USED PER DAY	
1942	Indoors	Outdoors
Jan. 7	14	—
Jan. 8–10	32	—
Jan. 13–16	20	—
Jan. 17, 19–24, 27–31; Feb. 1–7, 10–13, 19–28; Mar. 1–7, 10–14, 17–19, 24–31; Apr. 1–2	30	6
Apr. 4–8	60	6
Apr. 9–10; 14–17	30	6
Apr. 21–25, 30; May 1–9	30	30
May 13–15	30	—
May 19–31; June 1–10	30	27
June 17–23	—	27
June 24–27	—	25
June 30; July 1–3, 7–10, 14–18, 30–31; Aug. 1, 4–7	—	35
Aug. 26–31; Sept. 1–4, 22–29; Oct. 2	20	—
Oct. 30–31; Nov. 1–30; Dec. 1–24	15	5

TABLE 2.—*Statistics of indoor population of house mice at Davis, California*

1942	UNMARKED MICE CAPTURED			MARKED PLUS UNMARKED MICE CAPTURED			MICE KNOWN TO BE ALIVE		
	Males	Females	Total	Males	Females	Total	Males	Females	Total
January	60	76	136	60	76	136	60	76	136
February	24	31	55	49	51	100	59	60	119
March	3	27	30	21	48	69	26	51	77
April	2	5	7	11	26	37	11	26	37
May	0	0	0	1	4	5	1	4	5
June	0	0	0	0	0	0	0	0	0
July	—	—	—	—	—	—	—	—	—
August	0	0	0	0	0	0	0	0	0
September	0	0	0	0	0	0	0	0	0
October	0	0	0	0	0	0	0	0	0
November	2	0	2	3[1]	0	3	3	0	3
December	3	2	5	3	2	5	3	2	5
Entire year	94	141	235	94	141	235	94	141	235

[1] Includes one individual marked outdoors in August.

period to period, and that the marked individuals be dispersed at random among the unmarked. Intervals between trapping periods must therefore be short enough to avoid changes in the marked:unmarked ratio but long enough to ensure random distribution. In certain cases corrections for such aspects of Premise 2

as births-deaths and immigration-emigration have been achieved (Dowdeswell, Fisher and Ford, 1940; Jackson, 1948), but many of the variables involving Premise 1 have yet to be discovered and their effects evaluated. Without minimizing or depreciating the true value of the proportional method, its limitations should be kept in mind.

The trapping data have been analyzed to provide estimates of the population on successive days, and selected typical sequences have been compared with the number of individuals known to be alive on the day of the estimate (Table 3). These estimates fluctuated considerably from day to day. Except in the early days of the trapping, when relatively few mice had been caught, and again after the first week in April, when the population had greatly declined, the estimated numbers were consistently far short of the mice known to be alive. The forty estimates from January 20 through April 1 ranged from 8.3 to 80.0 per cent of the numbers known alive, with an average of 47.4 per cent.

These figures suggest that the population of this room was unstable and kaleidoscopic, daily fluctuating in size and shifting in composition. Many mice caught on one day were not taken the following day, and some were recaptured only after intervals of considerable length. This varied behavior may be attributed to differences in trappability, but it is also possible that some individuals may have been in other parts of the building, or even outside, during the intervals. Such mice, although known to have been alive, would technically not be part of the population of the room on the day when a given estimate was made.

The preceding statements may explain the discrepancy between the two sets of figures, but they do not give validity to the estimates. Evidently the marked individuals were not being dispersed at random through the population which was sampled. Obviously, whenever a population is not sufficiently isolated, but is part of a larger unit, this same difficulty is likely to arise. In the present study, reliable estimates were apparently precluded by a constantly changing population.

Age structure of the population.—Lack of criteria for judging the age of live individuals in the field is a serious handicap to population analysis. In the present study, three age groups were recognized by combining characters of relative size, weight, and breeding condition. These groups were as follows: (A) Small mice, weighing 9.5 to 12.5 grams, the females with imperforate vaginas, the males without noticeable enlargement of testes, and neither showing any signs of previous breeding; these were relatively young animals and were called *immatures*. (B) Relatively large mice, weighing 18 grams or more, with both sexes usually showing signs of sexual activity either past or present; these were called *adults* and were definitely mature individuals. (C) Mice not readily assigned to either of the above classes, ranging in weight from 13 to 17 grams and generally with little or no sign of sexual activity; these were termed *subadults*. Laurie (1946) found that external inspection does not give reliable estimates of reproductive status; a few mice of both sexes proved to be fecund at less than 10 grams and all females were mature at 15 grams although they were rarely pregnant under 12.5 grams. The age terms of the present study are thus somewhat crude and arbitrary, but they describe roughly the age structure of the population.

TABLE 3.—*Selected sequences of daily trapping data and estimated populations of house mice at Davis, California. The significance of the columns is as follows: (A) number of unmarked mice caught; (B) total number of mice caught; (C) total number of mice released; (D) number of recaptures of mice released on previous day; (E) estimated population at time of release, based on the equation* $\frac{\text{E of given day}}{\text{C of given day}} = \frac{\text{B of given day}}{\text{D of given day}}$; *(F) total population known to be alive at time of release*

1942		A	B	C	D	E	F
January	14	4	11	11	—	58	37
	15	14	21	20	4	50	49
	16	9	20	18	8	57	51
	17	8	19	19	6	—	56
	27	1	14	14	—	19	60
	28	1	16	15	12	23	60
	29	4	20	19	13	24	63
	30	2	18	18	14	35	63
	31	8	29	29	15	51	69
February	1	8	28	25	16	40	69
	2	2	19	18	12	—	68
March	1	0	2	2	—	6	47
	2	0	6	6	2	13	47
	3	2	11	11	5	24	49
	4	2	11	11	5	29	50
	5	2	13	13	5	27	52
	6	2	15	15	7	39	53
	7	6	26	25	10	—	58
April	4	0	11	11	—	20	30
	5	3	16	13	9	21	30
	6	1	16	14	10	26	29
	7	0	11	9	6	36	27
	8	0	8	8	2	32	25
	9	2	16	14	4	18	22
	10	0	13	11	10	—	18
May	1	0	1	1	—	3	5
	2	0	3	3	1	3	5
	3	0	3	2	3	4	4
	4	0	2	2	1	—	4
	12	0	1	1	—	3	4
	13	0	3	3	1	3	4
	14	0	1	1	1	—	4

The figures for that part of the population known to be alive from month to month have been analyzed for age composition (Table 4). This analysis has allowed for the development of immature and subadult individuals and their consequent transfer to older age groups when indicated by repeated observations. The respective percentages of the age groups in the total population for the month

provide an indication of the age structure. The percentage of subadults rose steadily from the least significant element in the population to the predominating one. Both adults and immatures steadily decreased from January through April (figures for May are too few). Despite the crudity of the criteria for age determination, the population apparently became more homogeneous as to age as it declined, finally being largely non-productive individuals. Such a trend would obviously lead to self-extinction.

TABLE 4.—*Age structure of the indoor population known to be alive from month to month. Study of house mice at Davis, California*

1942	MALES	FEMALES	TOTAL	PERCENTAGE OF POPULATION
January				
Adults	34	29	63	46.3
Subadults	12	5	17	12.5
Immatures	14	42	56	41.2
February				
Adults	31	19	50	42.0
Subadults	20	17	37	31.1
Immatures	9	23	32	26.9
March				
Adults	17	14	31	40.3
Subadults	9	20	29	37.7
Immatures	0	17	17	22.0
April				
Adults	7	4	11	29.8
Subadults	3	20	23	62.2
Immatures	1	2	3	8.0
May				
Adults	0	0	0	—
Subadults	0	4	4	80.0
Immatures	1	0	1	20.0

Growth rate of individuals.—The growth rates and changes in body weight of small mammals in natural environments are poorly known. It is difficult and often impossible to make the necessary measurements in the field. Furthermore, individuals are rarely caught frequently enough or over a sufficiently long period to indicate rate of development. Finally, the weight may fluctuate considerably in a short time; I have observed voles (*Microtus*) that increased 5 to 7 grams (at least 20 per cent) in body weight within five minutes through water consumption, despite previous access to water. No matter how accurately or frequently weights are taken, their interpretation is open to question. Nevertheless, weight records are of much relative value and should be made.

In the present study, some reasonably accurate and extensive weight records

were obtained. Figures for forty-four mice with records of thirty days or more between first and last weighings have been analyzed for weight changes (Table 5). Only seven mice showed gains of more than 2 grams; of these, only three, all subadult males, gained more than 3 grams. No other data for house mice developing under natural conditions are available for comparison. Green (1931) studied laboratory-bred individuals of "the 'Little' inbred strain of dilute brown non-agouti *Mus musculus*;" his growth curves indicate an average increase of weight for males over a 30-day period from 11 to 20 or from 15 to 21 grams and a corresponding gain for females from 11 to 17 or from 15 to 19 grams. These laboratory-reared mice presumably were kept under optimum dietary conditions so that their growth may not correspond to that of natural populations, but the mice considered in Table 5 seemed abnormally slow in their growth rates. In fact, with the few exceptions noted above, the increase in weight was so slight as to suggest that development was essentially at a standstill.

TABLE 5.—*Distribution of recorded weight changes in an indoor population of house mice at Davis, California, 1942*

AGE CLASS AND RANGE OF WEIGHTS (GRAMS) AT FIRST WEIGHING	NUMBER OF AVAILABLE RECORDS	NET CHANGE IN WEIGHT BETWEEN FIRST AND LAST WEIGHINGS (GRAMS)							RANGE IN NUMBER OF DAYS BETWEEN WEIGHINGS
		−			0	+			
		>2.0	1.0–2.0	0.5		0.5	1.0–2.0	>2.0	
Immatures (11.5–12.5)	8	—	—	—	1	3	3	1	32–97
Subadults (13.5–17)	24	2	1	1	4	7	3	6	31–88
Adults (18–21)	12	4	3	2	2	—	1	—	30–78

It has already been pointed out that the food supply in the room consisted chiefly of a small amount of grain and seeds accidentally scattered about on the floor and shelves. There was no more substantial source of food elsewhere in the building. The apparent lack of adequate food probably contributed to the failure in normal growth, and search for further food may have been a cause for constant shifting of the population. Laurie (1946) found a relatively low rate of pregnancy among 'urban mice' and suggested that this "is probably associated with the comparative instability of their habitat, i.e. the greater amount of disturbance to which they are subjected, and their more scanty diet."

Mortality.—Of the 235 mice caught, fifty-three definitely succumbed to the effects of trapping after histories of varying lengths. This mortality was distributed according to month as follows: January, 13; February, 16; March, 7; April, 15; May, 2. The percentage mortality in the population known alive rose sharply to about 40 per cent in April. The traps were almost always supplied with plenty of food to carry the mice through a 24-hour period under normal conditions of health. No pathological study was made of the dead mice, but notes were kept of apparent abnormalities. Most of these mice were already dead when the traps were opened; a few were moribund and incapable of maintaining natural equilibrium, and in one case there was paralysis of the hind quarters. Other

abnormal signs noted included pure white feces (? undigested rolled oats or flour) and dark brown (? bloody) urine. This scant evidence, together with the seemingly depressed growth rate, suggests that the population was in a precarious state of health, making it particularly susceptible to mortality factors. The limited food supply was probably insufficient to support the large numbers present, and slow starvation may have been the major factor for the poor health of the population.

Sex ratio.—The figures in Table 2 indicate a sex ratio of 66.7 males per 100 females for the 235 mice caught during the year in the one room. With the possible exception of February, this preponderance of females was apparent throughout all of the early months of the study. The marked population started in January with sixteen more females than males, and the additions in February brought seven more females than males, yet the population known to be alive in February apparently had an equal sex ratio. Therefore, females must have been disappearing from the population at a greater rate than males. This difference in rate does not seem to have continued, for in March there was again a greater abundance of females, largely through the addition of twenty-seven females and only three males. The inequality in sex ratio remained throughout the rest of the population decline.

Table 4 shows that females consistently exceeded males in the immature age group from January through April. In the subadult group, there was an excess of males in January and February, but more females than males in the subsequent months. Among the adults, males continued to outnumber females, but the decline of this age group reduced its effect upon the total sex ratio. The superabundance of females can apparently be attributed principally to an unequal sex ratio in the younger mice being added to the population. This discrepancy between the sexes might be explained as a difference in "trappability," but there was no evidence to support such a suggestion. An unequal and fluctuating sex ratio may well be characteristic of a population that is unstable in other respects. Laurie (1946) found a preponderance of females in the temporary populations inhabiting corn ricks.

THE OUTDOOR POPULATION

Occasional reports of "house mice" in fields and meadows suggested that the local increase in abundance was not confined to indoor populations. In January, 1942, fifteen to twenty traps were set in grass and herbs on the levee of Putah Canal, one mile south of the Seedhouse, to catch meadow voles (*Microtus californicus*) which were also abundant; the ten traps set in *Microtus* runways caught seven house mice on January 21 and nine on January 23. A few traps, later increased in number (Table 1), were placed outside the Seedhouse and run concurrently with those indoors to provide a check on the movements of mice.

Only twenty-one individuals were taken outdoors in the vicinity of the Seedhouse during the year (Table 6). The outdoor figures are therefore too small for analysis and because of differences in the extent of trapping cannot be compared directly with the figures for the indoor population. They suggest a less dense or

smaller population outdoors which, after the complete disappearance of the mice inside the Seedhouse, continued to exist without marked change.

Indirect information about the outdoor population was obtained by analyzing pellets of a barn owl (*Tyto alba*) which roosted in a tree near the Seedhouse (Evans and Emlen, 1947). This study covered approximately the same period (January, 1942, to January, 1943) as the house mouse investigation. During the year the owl caught at least 283 house mice, which formed 27.8 per cent of all food items represented and considerably more than that of any other prey species. These 283 individuals were taken by the owl as follows: between early January and April 17, 102; between April 18 and July 17, 75; between July 18 and October 23, 78; between October 24 and January 19, 28. Comparison with the data for other prey species (chiefly small mammals) shows that the decline in consump-

TABLE 6.—*Statistics of outdoor population of house mice at Davis, California*

1942	NUMBER OF UNMARKED MICE CAPTURED			TOTAL NUMBER OF MICE CAPTURED		
	Males	Females	Total	Males	Females	Total
January	3	0	3	3	0	3
February	0	0	0	0	0	0
March	0	0	0	0	0	0
April	0	0	0	0	1[1]	1
May	3	0	3	3	1[1]	4
June	0	0	0	0	1[1]	1
July	1	0	1	2	2[1]	4
August	4	1	5	4	1	5
September	—	—	—	—	—	—
October	0	1	1	0	1	1
November	2	0	2	2	0	2
December	3	3	6	3	3	6
Entire year	16	5	21	16	5	21

[1] Individuals previously marked indoors.

tion of house mice was accompanied by a corresponding rise in the take of pocket gophers (*Thomomys bottae*), the second most important food item. It is therefore not clear whether the downward trend in house mice represents a decrease in absolute or merely in relative availability. The hunting range of this owl was estimated to cover approximately 165 acres, much of which was potential house mouse habitat and of which the Seedhouse and vicinity formed but a small fraction. The pellet analysis indicates that over this larger territory the house mouse population may have undergone a decrease somewhat less severe than that suffered by the indoor population.

MOVEMENTS BETWEEN POPULATIONS

Indoors to outdoors.—Only three records of movement in this direction are available. An adult female, caught and released indoors on January 9, was not recaptured until March 13, when it was again taken indoors. Thereafter it was

caught indoors fairly frequently up to and including April 9, and on April 10 it was dead in one of the outside traps. An immature female, caught and released indoors on February 20, was taken indoors at intervals up to and including May 19; on May 20 it was caught in an outside trap. It was next taken on June 27, again outdoors, and several more outdoor captures were recorded up to and including July 14 when it was last taken. Another immature female, caught and released indoors on March 14, was taken at intervals, always indoors, up to and including May 15. It was next caught on July 1 in one of the outdoor traps and thereafter several times, always outdoors, up to and including July 30 when last taken.

Outdoors to indoors.—Only one mouse was known to have moved inside: an immature male, first caught and released outdoors on August 7, was not recaptured until November 1, when taken in an inside trap; it was not seen again.

These meager records show some contact between the indoor and outdoor populations. In view of the extensive trapping, it is surprising that more records of movements were not obtained, unless such movements were relatively rare. Probably it was no mere coincidence that the three movements from indoors to outdoors were in the spring and early summer and the single reverse movement in the fall. None of the mice captured indoors in November and December was adult or was known to have been present indoors earlier in the year, and the outdoor population was probably the source from which the beginnings of the new indoor population were recruited.

SUMMARY

A live-trapping study of house mice (*Mus musculus*) was carried on at Davis, California, from January 7, to December 24, 1942. Both indoors and out, mice were marked, examined, and released for recapture.

There were striking differences in the frequency of capture of various mice. Some were regular repeaters day after day, others were recaptured only after long intervals, and still others were never recaught.

During the year, 235 house mice were caught in a room twenty-one by forty-two feet. This indoor population declined rapidly and disappeared completely by June. A new population began to develop in November, but did not approach the concentration of the previous winter.

Daily estimates of the indoor population by the proportional or 'Lincoln Index' method consistently fell far short of the numbers of mice known to be alive. Marked individuals were evidently not being dispersed at random through the population which was sampled. This suggests that this population was constantly fluctuating in size and composition.

As the indoor population declined, it apparently became more homogeneous as to age, finally consisting largely of non-productive individuals.

Only seven of forty-four mice showed gains in weight exceeding 2 grams over periods of thirty days or more. In general, the increase in weight was so slight as to suggest that development was essentially at a standstill. The lack of an adequate food supply probably contributed to this failure in normal growth.

A few observations of mortality due to trapping suggest that the indoor population was in a precarious state of health, in which slow starvation may have been the major factor.

The sex ratio for the 235 mice caught indoors was 66.7 males per 100 females. The preponderance of females was apparently due primarily to a superabundance of this sex in the younger mice being added to the population.

Scant trapping figures for the outdoor population suggest a less dense or smaller population which did not disappear simultaneously with the indoor population. A study of barn owl pellets indicated that the outdoor population may have undergone a somewhat less severe decrease.

Three mice were known to have moved from indoors to outdoors, and one moved in the opposite direction. Such movements were apparently relatively rare. Those from indoors to outdoors occurred in the spring and early summer, and the reverse movement was in the fall. The outdoor population was probably the source from which the beginnings of the new indoor population were recruited.

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SEX AND AGE DETERMINATION IN THE OPOSSUM

By George A. Petrides

Outside of the laboratory, where it has been rather intensively studied, the opossum (*Didelphis virginiana*) has been little investigated. In many states throughout its range, the opossum ranks as an important fur species and in some it is valued for its meat. Though the price of the meat or fur of an individual opossum usually is low, collectively the annual opossum crop is of considerable economic significance.

Despite its importance, scarcely any attempts have been made to conduct state-wide surveys to serve as guides in the management of opossum populations. This probably is due in part to a lack of suitable techniques for collecting data bearing on the species. Sex ratios and numbers of young per adult female are important indicators of productivity, and under some conditions these ratios also may be used to measure the sizes of animal populations and the extent of fluctuations therein (Kelker, 1945; Petrides, 1949). The full extent of their usefulness in studying opossum populations has not been explored.

The present study was undertaken primarily to determine methods for rapidly determining the sex and age of opossums particularly during the trapping season. Data reported here which are applicable to other seasons were collected incidental to studies of other species and are not as detailed for these periods as could be desired. Information is provided, however, which would seem to be useful in aiding future intensive field investigations into the life history and ecology of the opossum as well as in assisting in more extensive surveys. Since during the breeding season the capture of a female usually also results in the capture of a litter, the opossum lends itself unusually well to studies of reproduction. Data are provided permitting the determination of the age of immature opossums, thus establishing a basis for estimating the dates of reproductive events.

Acknowledgments.—This study, a part of my doctoral dissertation, was completed while I was serving as Assistant Leader of the Ohio Cooperative Wildlife Research Unit at Ohio State University. I am indebted to the entire staff of the Department of Zoology and Entomology at the Ohio State University and especially to Drs. Charles A. Dambach and Daniel L. Leedy for their constant interest, encouragement, and advice. These men and Dr. Earl L. Green of the University staff critically reviewed the manuscript. Dr. Eugene Dustman, now Leader, Ohio Wildlife Unit, and Messrs. Robert Bowman, Robert Linder, Paul Moore, Ralph Ramey, and William Wiseman, undergraduate assistants, all helped from time to time in various phases of the study.

The Ohio Division of Conservation and Natural Resources and Commissioner H. A. Rider, Executive Director of this organization, deserve recognition for their support of the project as a portion of the program of the Ohio Cooperative Wildlife Research Unit. Messrs. Joseph Schwartz, owner, and Edward Frazier, skinner, Columbus Hide and Fur Company, Columbus, Ohio, generously permitted the examination of bought pelts and carcasses. Mr. Frazier also helped greatly by saving certain specimen materials.

Study material.—During this study, forty-eight different individuals were live trapped a total of sixty-one times, forty-nine whole or skinned carcasses were studied, 377 pelts were examined, two animals were held captive for a few months each, and a number of museum skins and skulls were examined. The trapping was conducted largely in the Botany Garden on the Ohio State University campus. A few live specimens also were taken elsewhere in Franklin County, Ohio. The live-trapping period was mainly from July, 1946, to October, 1947. The fur dealers' pelts and carcasses were examined between December 3, 1947, and January 17, 1948, at Columbus. These specimens could have been killed as early as November 15, however, and for the most part probably came from the ten counties nearest that city.

Growth of young opossums.—Hartman (1928 and earlier papers) and McCrady (1938) have described the early stages of the development of the opossum in great detail. After a brief gestation period of just under thirteen days, the young are born in a naked and relatively undeveloped condition. Nevertheless, each makes its way into the mother's pouch and attaches to a teat. Within a few days after nursing begins, the nipples become enlarged and the young opossums are unable to release their hold. They remain in place, therefore, until, after considerable growth, the jaws can be opened and the nipples released. Over two months are spent in the pouch and an additional period of about thirty days passes during which the young travel with their mother.

When 90–100 days old the family breaks up and the young begin independent existences. At this time the young animals are only slightly larger than rats and have incomplete series of teeth. As they undergo rapid growth additional premolars and molars are acquired. Sexual maturity often is reached before a large size is attained. One female was tagged during this study on October 3, 1946, when she weighed a mere 340 grams. On April 1, 1947, she was recaptured with nine young in her pouch and was found to weigh 1800 grams. From these data it is estimated (see beyond) that the mother was born about June 1, 1946, and successfully mated about February 2, 1947, at an age of approximately eight months. Another female has an almost identical record. Reynolds (1942) records a similar instance in Missouri of a small October female breeding after being released from captivity the following April. Hartman (1928) records breeding females which weighed as little as 660 grams, but their small size could have been a result of captive conditions. It is apparent, however, that young born late one year may breed early during the next reproductive season.

While no tagged female was observed with two litters during this study, the estimated birth dates of trapped young animals extended from early February to late May or early June. Probably two litters per female are born frequently in Ohio as they are in Texas (Lay, 1942) and in Missouri (Reynolds, 1945) Since some females which had not bred were found as late as April in Ohio during this study and in Missouri by Reynolds (1942), apparently not all young females produce two broods. In Texas a limited number of recaptured females indicated to Lay (1942) that nearly all females there may bear two litters per year.

From observations during this study and at other times, it appears that, in general, males may attain a larger size than females. Of forty-eight females weighed and measured, none weighed over 3000 grams or had a total length of more than 760 mm. Of thirty-five males thus examined, seven exceeded these dimensions. The two largest weighed 4734 and 4366 grams and were 820 and 840 mm. long, respectively.

SEX DETERMINATION

Pouch young.—The sex of an opossum is easily distinguished from the time it is eleven (McCrady, 1938) to seventeen (Reynolds, 1942) days old—a sightless, jawless, foetus-like suckling in its mother's pouch. Pouch young, after this age, display obvious scrotal rudiments in the male, despite their embryonic appearance otherwise (Pl. I). In many small, naked female young, the outlines of the pouch and the eleven to seventeen minute nipple rudiments are distinctly evident. McCrady (1938) has described in some detail the early growth of the sex organs in the opossum.

Free-living individuals, and carcasses.—At all ages after the first two weeks the presence of the prominent scrotum identifies the male; its absence is sufficient evidence of a female. The pouch may not be well developed in young females and, in any case, may not be very obvious unless occupied by large young. The opening is in the mid-ventral region (Pl. II). The penis, when not erected, is normally withdrawn into the urogenital sinus.

Pelts.—Opossum skins are commonly prepared as cased pelts with the fur side in. They are most easily examined after they have been removed from the stretchers. The sex and age of the pelts can be determined, however, even while they are fresh and on board stretchers, but to do so increases the chances for error.

Probably because of their limited value, opossum pelts rarely seem to be well prepared. In Ohio, at least, they are commonly ripped off the carcasses as rapidly as possible. The scrotum of males is allowed to remain on the skins in the majority of cases. Where it has been cut off there usually still remains a black blotched area of nearly bare, heavily pigmented skin which is characteristic of the scrotum, scrotal peduncle, and adjacent belly skin of the male opossum. The thin skin of the belly region sticks to the carcass and is torn away from the pelt in many female and in some male skins. Plate II, upper, shows a male skin (left) and two larger female pelts (center and right). As indicated in this photograph, the location of the pouch of the female, even in the skins of immature animals, can be distinguished easily from the flesh side where the belly remains in place. Even the locations of the teats are usually evident. As will be mentioned again later the pouch fur of adult females is sparse and is usually of a peculiar dark burnt-orange color. When its presence is in doubt a finger may be inserted in the skin to probe for the pouch. This is often the easiest way to determine its presence. Sometimes it may be advantageous to hold the skin up to the light, peering into the furry interior to perceive the darker pouch folds by transmitted light. Where this area is torn away (as in the right hand pelt, Pl. II, upper) a search for remains

of the pouch or nipples should be made along the edge of the torn area before assuming that the skin is from a female. Some skins cannot be sexed accurately

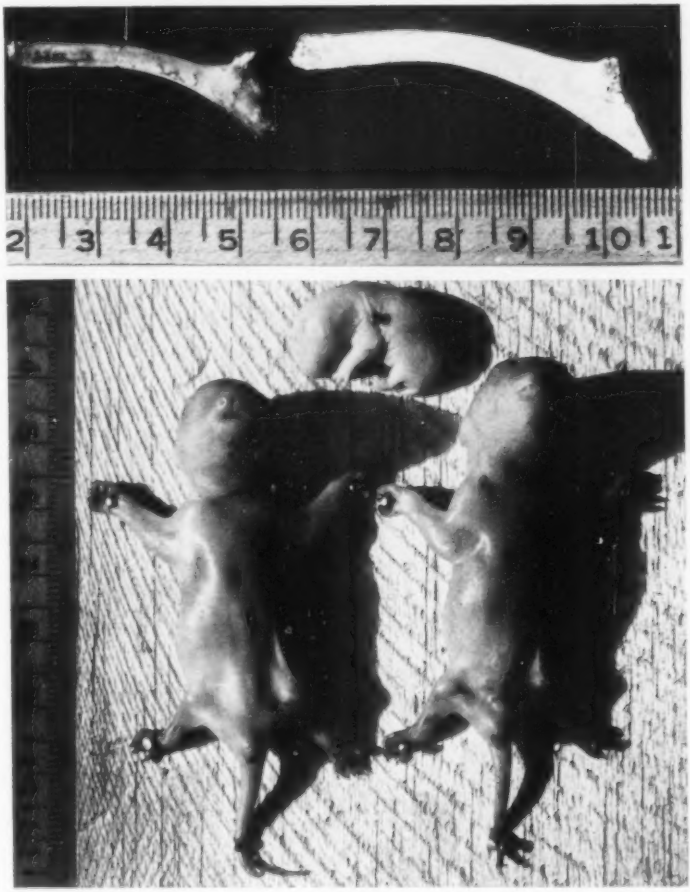
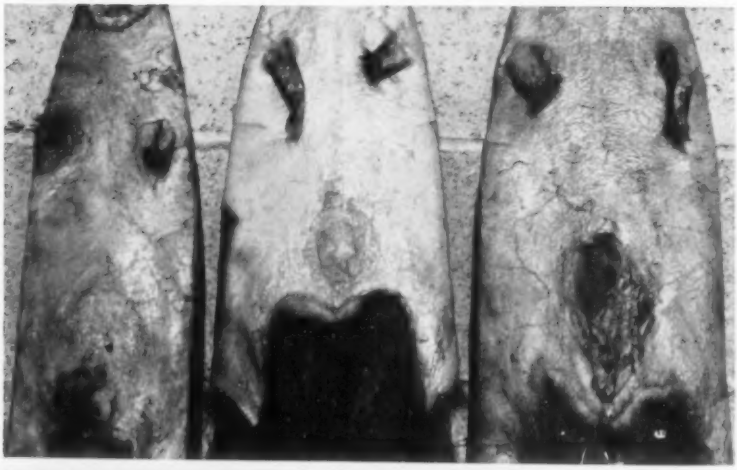


PLATE I

UPPER: Epipubic bones of immature (left) and adult (right) opossums. Both specimens were collected on January 3, 1948.

LOWER: Pouch young of opossums displaying sex characteristics. Note scrotum of male (right) and outline of pouch of female (left). Large young about 45 days old. Small specimen about 12 days old.

if the belly region is badly damaged. Sex ratios derived from hunting and live trapping, however, are similar to those from pelt examination (see beyond) which may indicate that pelt examination methods are not likely to be far wrong.



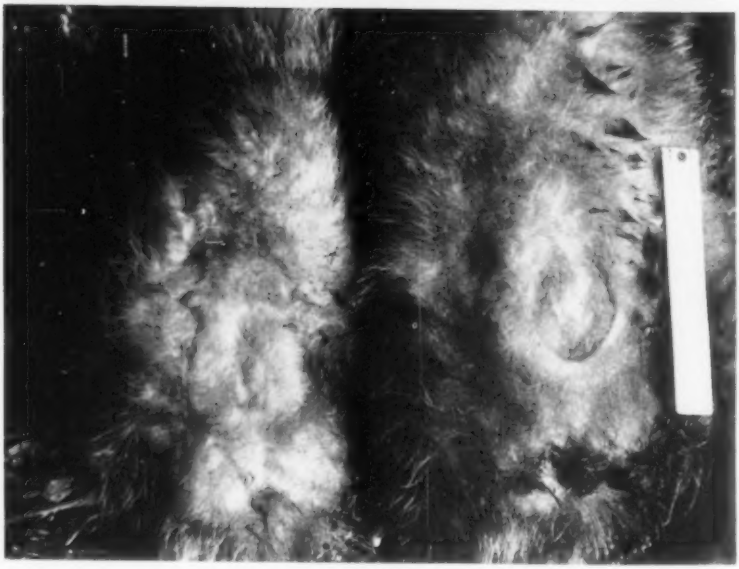


PLATE II

UPPER: Opossum pelts: "small" male to the left; two "medium" females to the right. The pouch area has been torn in the female at the extreme right.

LOWER: Pouch characteristics of immature and adult opossums.

AGE DETERMINATION

Pouch young.—This study disclosed no new information on the development of very young opossums. Hartman (1928) provides growth curves for pouch

young up to fifty-six days by weight and up to ninety days by length. He also discusses other criteria of age through about the third month and provides a curve of length on weight up to 200 millimeters and 180 grams. Moore and Bodian (1940) and Reynolds (1942) give additional data of the same type.

From the information provided by these workers, Table 1 has been devised to aid in estimating the dates of birth of pouch young. It is emphasized, however, that all of the measurements of young opossums there presented apply to average individuals. Insufficient data are available to determine normal deviations from the average. Reynolds (1942) found in captive animals that young of the same age varied in size and weight apparently according to the amount of food eaten by their mothers. He did not believe that weight or length beyond forty

TABLE 1.—*Average ages of opossum pouch young according to length and weight (Modifications of the data of Hartman, 1928; Moore and Bodian, 1940; and Reynolds, 1942)*

AGE, DAYS	SNOUT-RUMP LENGTH (IN MM)[1]	WEIGHT (IN GRAMS)
1	13	0.13
5	17	0.4
10	24	0.9
15	30	1.3
20	33	1.7
25	40	2.4
30	45	3.9
35	53	5.4
40	60	7.0
50	75	13.0
60	100	25.0
70	125	45.0
80	150	80.0
100	180	125.0

[1] Following the system used by Moore and Bodian and by Reynolds, the distance between the nose and the anus is measured.

days of age were as useful age criteria as were other characteristics. Hartman's data (1928) indicate that the young within a litter may vary in size to such an extent that there appears to be an age difference of five days or so between the extremes. Differences between the ages at which individuals of different litters open their eyes, for example, also apparently may vary by ten days or so. Fairly accurate estimates of the age of pouch young should be possible by using the averages of measurements for each litter. Probable dates of birth and mating (birth date minus 13 days) are easily derived.

It may be helpful to record a few total length figures to aid in computing snout-rump measurements where only total lengths are available. These data are for pouch young whose age was estimated from Table 1. The first figure is total length, the second is snout-rump length, and in parentheses is the age in days; 35, 30 (15); 55, 47 (32); 85, 65 (42); 245, 145 (78).

Attributes other than measurements also are of value in determining the ages

of juvenile opossums. The following facts have been assembled from Hartman's (1928) data. In regard to teeth, this author does not indicate whether he refers to those of the upper or the lower jaw. From observations of older animals during the present study, the teeth of the lower jaw are usually advanced in development over those of the upper. Other age criteria of juvenile opossums are as follows:

One to three days: The young animals can re-attach themselves to the teats after being removed.

Seventeen days: The sex organs are evident, according to Reynolds (1942). McCrady (1938) says they are discernible at about eleven days of age.

Thirty-five days: Downy hair is visible with a hand lens: vibrissae begin growth.

Fifty days: The size of a house mouse; hair is short and sparse, but becoming pigmented dorsally; eyes and jaws sealed.

Sixty days: The eyes and jaws open; the body is completely covered with short dark hair; the first tooth, the third premolar, erupts; elongated teats of the mother permit the young to lie outside the pouch while nursing.

Seventy days: The young may venture away from the mother for short distances, returning to the pouch; quite furry.

Seventy-five days: The second tooth, the second premolar, erupts.

Eighty to ninety days: The young are weaned; the size of large rats.

Eighty-five days: By this time, the last four incisors, the canines and the first premolars, erupt.

Ninety-five days: The first incisors and first two premolars are present; only the three molars and the third premolar remain to be cut.

(In contrast to these data of Hartman's some observations made in Texas after this manuscript was prepared indicate that in at least some wild opossums the tooth stage indicated by the formula $\frac{4130}{4131}$ may be reached at about 80 days of age.)

Post-pouch stages: In opossums, easily observed changes due to age occur in size and weight, and in pouch and tooth development.

Size and weight.—While measurements of length and bulk are not unrelated, animals of the same length may vary greatly in weight. Conversely, specimens of similar weights may not have comparable dimensions. The probable range of such variation cannot be reliably determined from the few comparable measurements at hand. Instances were recorded, however, involving both weights and lengths where a larger animal would be more than 25 per cent heavier or longer than a smaller individual in the same category of length or weight. Whether it is size or weight that is more closely associated with age is undetermined, though length at least would appear to be less subject to temporary fluctuations which might influence weights.

During the course of the study, a few data were collected for retrapped animals which indicate the degree of growth for those individuals during the intervals between trappings. These are plotted in Figure 1 in the form of curves of total

length and weight on age. In all cases, the original age of the individual was estimated. It is only the rate of growth between the known dates that is known to be above question. The fact that these plotted rates of growth showed similar slopes would seem to indicate that the growth curves shown (Fig. 1) may approximate the growth curves of average individual opossums. The data failed to show any differences between the sexes during the ages covered by the curves. From these curves the probable ages of juvenile opossums may be estimated.

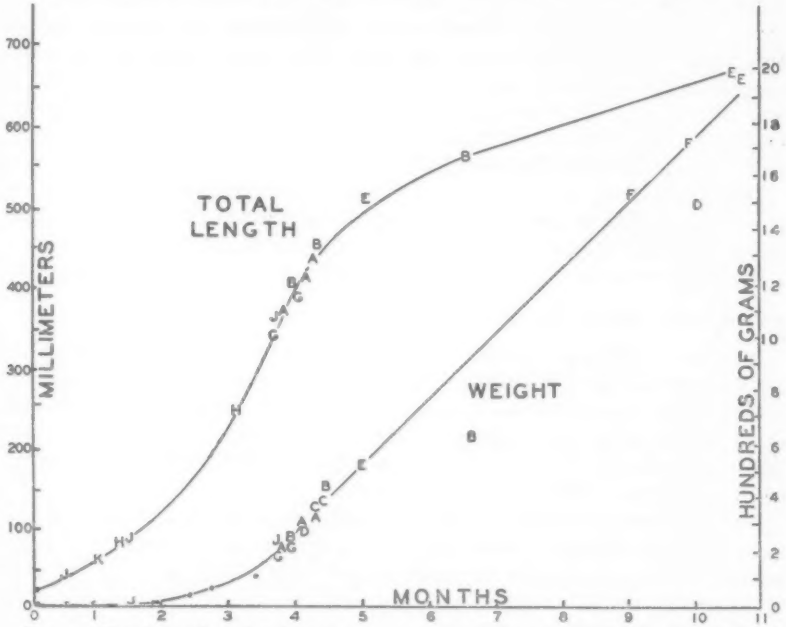


FIG. 1.—Total length and weight increases in tagged immature wild opossums. Specimen numbers: from Hartman (1928) and Moore and Bodian (1940); A, No. 414m; B, No. 418f; C, No. 56m; D, No. 59f; E, No. 88f; F, No. 705f; G, No. 468m; H, young of No. 331f; J, young of No. 88f; K, young of No. 703f. Note: letters following specimen numbers indicate sex; H, J, and K are averages for the litters.

Pouch development.—Two sets of characteristics, which obviously are related to the breeding experience of females, prevail in opossum pouches. Females which have not bred have white, clean, fully-furred pouches which may be shallow or practically absent in small individuals even in winter. The teats in such pouches are tiny and white and must be sought out in the fur. A teat of a large nonbreeding April female, doubtless born the previous year, measured only 1.5 millimeters in diameter and was only one millimeter long. On pelts, the pouches of immature females invariably are less flabby, less fatty, less dark, and less prone to tear out than are those of breeding specimens (Pl. II).

Females which have bred possess pouches which are scantily haired and of a peculiar rusty color. Both the inside of the pouch and the hairs immediately bordering its entrance are so tinted. The teats are much enlarged, usually being three millimeters in diameter even in dried winter pelts. No skins or specimens of females were seen in which there seemed to be any doubt as to whether the animals had bred or not. In those female specimens handled in which the dental formula was checked (see beyond), all seven which had bred had complete dental series; all eleven immature animals carried incomplete sets of teeth. No evidence was found that young females might breed during their first summer, though this possibility cannot be entirely dismissed. The smallest adult female specimens seen were beyond doubt at least in their second year. This was true not only of carcasses and live-trapped animals, but also of the pelts of thirty-one mature females. All of the latter group fell into "medium" and "large" size classifications; none were clasified as "small" (see beyond).

Unless it is found that a significant proportion of adult females fail to breed it seems reasonable to accept the present evidence that most first-year and adult female opossums can be distinguished on the basis of pouch characteristics.

Dental development.—A mature opossum with a full set of 50 teeth has these arranged according to the formula: $\frac{5\ 1\ 3\ 4}{4\ 1\ 3\ 4}$.

Hartman (1928) reported that young opossums acquire the last four incisors, the canine, and the first premolar by the time they are eighty-five days old. By ninety-five days of age, he says, only the last three molars and the third premolar remain to be cut. Reynolds' (1942) statement that the young complete the development of a full set of teeth when eighty to ninety days old is not borne out by Hartman's (1928) or the present study.

In the present investigation, the numbers of premolars and molars present, the length and distance between the canines, and the general amount of tooth wear were compared in both sexes with size and, in females, with age as indicated by pouch conditions. It was evident that the jaw teeth are increased regularly by additions from the rear until the full complement of three premolars and four molars in each jaw is attained. The lower jaw was commonly advanced over the upper with respect to the number of jaw teeth evident. There was a perfect correlation in six females between a full set of teeth and an adult-type pouch.

Conversely, twelve females with incomplete dental series $\left(\frac{5\ 1\ 3\ 3}{4\ 1\ 3\ 4}\ \text{or less}\right)$ were juveniles according to pouch criteria. It may be assumed, similarly, that males are also characterized according to age group by the number of teeth present. Among adults it was thought that occasional specimens with well-worn teeth were three years old or older. The canine teeth especially, in such specimens, showed obvious extreme wear. No replacement of teeth was noted in adults.

The third premolars carried early in life apparently are replaced by a different type at about the time that the second upper and the third lower molars come in. These juvenile teeth are multi-cusped; those replacing them are equipped with single sharp tips.

The limit to the age and time of year when the number of teeth present serve to mark young of the year was indicated only by one specimen which, though a young female by pouch characteristics, had nearly completed the growth of its last molars on January 17. There is no reliable estimate of its exact age. By weight, this animal may have been only nine months and three weeks old; by total length, it could have been older. It seems likely that its weight was abnormally low at the time of capture. Since young opossums doubtless are born at least as early as February 1 in Ohio, the number of teeth as an age criterion may not be completely reliable after about December 1.

Since there was no assurance that the teeth of animals in captivity would be replaced at the same rate as in the wild, no attempt was made at first to keep captives. McCrady (1938) states that the teeth of caged opossums are often abnormal. As a part of the present investigation, though, a female originally tagged when quite small and later recaptured several times was held captive for a time

TABLE 2.—*Record of tooth replacement in a captive opossum*

DATE	PREMOLARS AND MOLARS	THIRD PREMOLAR	CANINES[1]	ESTIMATED AGE IN MONTHS
Jan. 4	$\frac{2}{2}$	Juvenile	6 x 9.5 mm.	6.5
Feb. 15	$\frac{2}{2}$	Juvenile	7 x 10 mm.	7.8
Mar. 20	$\frac{2}{2}$	Adult	7 x 15 mm.	9.0
Apr. 19	$\frac{2}{2}$	Adult	7 x 15 mm.	10.0
May 20	$\frac{2}{2}$	Adult	—	11.0

[1] Length from the gum line to the tip × distance between the centers of the tips of the upper canines.

in 1947. Its record of tooth changes in captivity is shown in Table 2. Emergency circumstances forced the release of this animal on the last date. The specimen appeared to be in good health at all times. When first caged it seemed smaller than average possibly as a result of its selection of a city alley as headquarters after it was last seen on the campus as a youngster on October 19, 1946. Its estimated birth date was about mid-June, 1946.

By comparing the tooth numbers for forty-eight specimens with the growth curves of Figure 1, it is possible to derive an empirical table for estimating the age of post-pouch young by tooth formulas. The first tooth formula is derived from Hartman's (1928) statements. No attempt is made to distinguish deciduous from permanent teeth in these formulas.

Approximately three months ..... $\frac{5\,1\,2\,0}{4\,1\,2\,0}$

Four months ..... $\frac{5\,1\,3\,1}{4\,1\,3\,2}$

Five to eight and one-half months ..... $\frac{5\,1\,3\,2}{4\,1\,3\,3}$

Seven to eleven months ..... $\frac{5\,1\,3\,3}{4\,1\,3\,4}$

Ten months plus ..... $\frac{5\,1\,3\,4}{4\,1\,3\,4}$

To check in some way the probable validity of these data in other parts of the country, thirty-five skulls were examined in the U. S. National Museum. These specimens were from nine states ranging from Texas and Georgia north to Maryland, Ohio, and Wisconsin. Eleven were from the Pisgah National Forest, North Carolina. Only three were from other than the November–February months. None of these skulls indicated conspicuously earlier development than was found in Ohio specimens. The earliest skull just acquiring the last molars was from a Maryland male (USNM 119040) dated November 19. No other such specimen was dated before the first of the year. Because of the cleaned condition of the skulls, these last growing molars were evident in this specimen whereas in a carcass or live animal, a considerable period might have been required for them to appear through the gums.

The measurements of these skulls served to emphasize the large size that may be attained by some males during their first year. One Ohio skull (USNM 99627), dated February 7, had upper canine teeth which measured 17 millimeters long and 18 millimeters between the tips, yet the upper rear molars apparently were still growing when the animal was killed.

Gilmore (1943) indicates that *Didelphis paraguayensis* in Brazil has a sequence of tooth replacement correlated with age which is very similar to that of *D. virginiana*.

Sagittal crest.—Several skulls whose worn teeth indicated an age of over one year also possessed sagittal crests which were slightly to greatly eroded. In extreme cases the ridge was jagged, rough, and fissured. Such specimens may represent three-year-old animals.

Radial epiphysis.—X-ray photographs of the paws of opossums indicated that the closure of the epiphyses at the distal ends of the radius and ulna occurred too early in the year (at about the time that the 5/6 jaw teeth were coming in) to be of any practical value in conducting trapping season age ratio surveys.

Epipubic bones.—Toward the end of the study a few observations indicated that the epipubic bones, which project anteriorly on either side of the pouch region from the ventral portions of the pelvic girdle in both sexes, are larger in older animals than in first-year young. The following measurements were made of cleaned, separated bones (Pl. I) from dressed carcasses whose sex was not known. These specimens were all seen on January 3, 1947. Three first-year specimens, with the last upper molar still uncut, had epipubic bones which measured 37, 40, and 43 mm., respectively. In three adults with full dentition the bones measured 45, 48, and 50 mm., respectively. More study is needed to determine the extent of usefulness of the length of this bone as an age criterion beyond the period of usefulness of the teeth.

SEX AND AGE RATIOS

Pouch young.—The ease with which average sex ratios may be obtained in pouch young should be exploited by wildlife biologists. Data on the sex ratio of opossums soon after birth may be obtained by the examination of young in the pouches of living or killed females. In live specimens care should be taken not to detach the young animals from their mothers' teats, but this requires no great skill on the part of the technician.

The five broods old enough to sex which were examined during this study comprised twenty-one males and twenty-seven females. Hartman (1928) lists sexed specimens of pouch young in his appendices B and C. Presumably, they were selected from among the total offspring in a random manner. He mentions thirty-four males and twenty-nine females in his discussions of other matters.

Post-pouch stages.—Some sex ratios which have been determined for adult and sub-adult opossums are listed in Table 3.

TABLE 3.—*Sex ratios of opossums*

STATE	METHOD OF COLLECTION	SEASON	NUMBER OF ANIMALS	PER CENT MALES	AUTHORITY
Missouri	Hunters reports	Winter	2185	57	Bennitt and Nagle (1937)
Texas	Live traps	All year	117	57	Lay (1942)
Missouri	Largely pelts	Dec.–Jan.	1076	58	Reynolds (1945)
Missouri	Largely hunting	All year	116	55	Reynolds (1945)
Ohio	Largely pelts	Dec.–Jan.	330	54	Present study
Ohio	Live trapping	All year	48	42	Present study

The pelt figures for the present study (Table 3) are for 1947–48 specimens only, with a few carcass records added to the pelt data. If fifty-three sexed specimens from 1946 are added to the above 330, the sex ratio becomes 59 per cent males to 41 per cent females.

Whether the sex ratios of Table 3 can be interpreted to mean an actual preponderance of males in the wild is debatable. It is well known that male opossums are more prone to move about during cold weather than are females. Reynolds (1945) has shown a positive correlation between a nearly balanced sex ratio and relatively warm winter weather among Missouri-trapped opossums. He found the reverse also to be true.

It is interesting to note that the large-sample ratios derived by hunting and live trapping even at other seasons are similarly unbalanced, but whether they can be interpreted to indicate a real overabundance of males, or merely an apparent excess resulting from other errors in collecting data, is not clear. Future age-ratio information may assist by indicating the age group depleted and hence the probable cause of the apparent unbalanced sex ratio.

No age ratios seem to have been published for wild opossums except those referring to pouch young. During this study, forty-eight opossums (excluding

pouch young) were live trapped between June 1946 and October 1947. By sex and age groups there were twenty males and twenty-eight females, fourteen males and twenty-three females of which were young of the year. This sample is small, but the ratio of seven young per adult female is close to that determined from the pelt survey, given beyond.

Using fur dealers' pelts, an attempt was made to determine age ratios in female opossums on the basis of pouch characteristics. Tabulations were made of the pelts of both sexes, and size as well as sex and age was noted. These are listed in Table 4. No measurements were made of the size of the pelts. The skins were merely classed as "small," "medium," and "large" much as a fur buyer would

TABLE 4.—*Sex and age ratios derived from opossum pelts from Ohio*

SIZE	MALES	ADULT FEMALES	YOUNG FEMALES	ALL FEMALES	SEX DOUBTFUL
			1946		
Large	4	2	0	2	1
Medium	19	1	7	8	2
Small	10	0	3	3	6
Not noted	7	0	0	0	0
Totals	40	3	10	13	9
			1947		
Large	36	4	0	4	2
Medium	97	25	71	96	13
Small	28	0	18	18	8
Not noted	4	1	4	14	0
Totals	165	30	93	137	23

1947 Sex ratio: 165 males to 137 females, or .546:.454.
1947 Age ratio of females: 3.1 young per adult.

grade them. Plate II shows a "small" male and two "medium" female pelts against a background of standard-size concrete blocks. Several males could have been termed "extra large," but it was desirable to limit the number of classification headings. Most of the pelts were from animals trapped in central Ohio during the open season of November 15, 1947, to January 15, 1948. A few skins from the same area were held over from the corresponding trapping season of 1946–47. Assigning adult to young ratios from one sex to the other is a practice of dubious reliability and hence it is not possible to learn accurately the proportion of young animals among males. Since there were about three female young per adult female in both years, an estimate of six young of both sexes per adult female is probably not far from the true figure for young surviving until their first winter. For most survey purposes, age ratios for females alone probably are adequate to indicate the comparative success of reproduction from year to year

(Petrides, 1949). Where entire carcasses can be seen early enough in the year, age ratios may be derived for both sexes, as has been described.

LONGEVITY AND POPULATION TURNOVER PERIOD

As an incidental consideration, there has been some discussion in the literature of average longevity in the opossum. Hartman (1923), from observations of captive specimens, thought it might be at least seven years. McCrady told Reynolds (1942) that he would make a similar estimate. Lay (1942) believed opossums have a "relatively short life span" in the wild. Reynolds (1942) found evidence which might indicate a life span including only one winter, though this might be extended in mild winters. If the figure of six young per female can be taken as representing average conditions in the wild and if we can assume for this purpose a balanced sex ratio, then the average longevity in a stable population according to a formula originally proposed by Burkitt (1926) and slightly modified here is:

$$L = \frac{1}{j} = \frac{1}{.75} = 1.33 \text{ years}$$

In this equation, L is the average longevity of opossums which survive to the end of their first year and j is the percentage of young in the population. Using the same sex and age ratios, the probable population turnover period and maximum life span (see Petrides, 1949) may be estimated to be:

$$T = \frac{\log. 0.005}{\log. 1 - j} + 1 = \frac{\log. 0.005}{\log. 0.25} + 1$$

$$= \frac{-2.301}{-.602} + 1 = 4.8 \text{ years}$$

Here T is the number of years required for the young produced during a certain year to be reduced to 0.5 per cent of their original numbers, that is to the practical vanishing point.

SUMMARY

Methods were investigated for distinguishing sex and age in opossums, particularly during the winter trapping season. The sexes of young opossums can be distinguished after about the second week in the pouch by the presence or absence of a rudimentary scrotum. Usually remnants of the scrotal area or pouch are present on skins permitting the derivation of sex ratios by examination of fur dealers' pelts.

A table, largely compiled from the literature, permits the estimation of birth dates for pouch young by means of length and weight mesurements. Growth curves from records of retrapped animals are provided for the determination of approximate ages in young wild opossums up to about ten months of age. First-year, non-breeding females are distinguished from older, breeding females by the distinctive rusty color, scanty fur, and large teats in the pouches of animals in the latter group.

First-year animals of both sexes may be distinguished from adults during most of the year by their incomplete dental formulas. Sex ratios of pouch young, and sex and age ratios of older animals, were computed. A probable average longevity of 1.33 years was determined mathematically for animals surviving until the end of their first year with 4.8 years being required for the young produced one year to be reduced to 0.5 per cent of their original numbers.

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NATURAL GAME LICKS IN THE ROCKY MOUNTAIN NATIONAL PARKS OF CANADA

By I. McT. Cowan and V. C. Brink

Most of the arid and semi-arid areas of the northern hemisphere are inhabited by some form of ungulate mammal. It seems probable, from our experience, that in most of these areas there are local soil deposits which are sought out by the ungulates and eaten or licked for their mineral content. Also, there are heavily mineralized springs that possess an especial attraction for ungulates.

Considering the great abundance of such licks, their wide distribution, and the wealth of animal species, wild and domestic, that use them, it has been astonishing to us to find so few published references to the content and utilization of licks by the Artiodactyla.

Rush (1932) implied that elk in Yellowstone Park made use of mineral springs as a supplement to the normal mineral intake supplied by the fodder. He gave analyses of four mineral springs so used, but made no comment upon the significance of the various minerals and salts shown to be present.

Honess and Frost (1942) gave considerable attention to the licks used by bighorn sheep (*Ovis canadensis*) in Wyoming and, in the same publication, Beath discussed the significance of the licks in the diet of bighorn sheep. The analyses of five licks are presented. It is pertinent to note that phosphorus in the form of P_2O_5 was present in all five licks, while sodium was present in measureable quantities in but two and chlorine in just one of the two. Calcium oxide was present in three of the five. It was concluded that the sheep were probably seeking the phosphorus in most of the licks but that the sodium chloride may have been the attraction in one.

Dixon (1939) reported upon one lick from Mt. McKinley Park, Alaska, and two from California. In the first, calcium phosphate was suggested as the important element, in the others sodium chloride.

Brief mention is made by Chapline and Talbot (1926) of the use of natural licks by cattle, horses, and wild game. They imply that the soil is eaten with the primary purpose of obtaining common salt. On the other hand, there are instances on record of natural licks having an important dietetic influence, apparently based largely upon the presence in them of certain trace elements.

In the Rocky Mountain National parks of British Columbia and Alberta, Canada, mineral springs attractive to game, and natural mineral licks, are abundant and widely distributed. In this area there are large populations of bighorn (*Ovis canadensis*), mountain goat (*Oreamnos americanus*), moose (*Alces americana*), elk (*Cervus canadensis*), caribou (*Rangifer arcticus*), mule deer (*Odocoileus hemionus*), and white-tailed deer (*Odocoileus virginianus*)—all these species make use of the licks to a greater or lesser degree.

In general, the use of licks by game in the Canadian Rocky Mountains is confined to the summer months. This applies as much to the dry earth licks as it does to those rendered unavailable in winter by freezing, and it is thus concluded that the seasonal use is, in part at least, based upon factors other than those of

availability. Animals have been observed on the licks from late April to September, but the period of heaviest use is in June, July, and August.

Young animals in their first summer have seldom been observed to eat the soil of licks or to drink at mineral springs; no other age or sex difference, in degree of patronage, was noted.

It has been generally assumed that the primary importance to game of natural licks and mineral springs was in the betterment of the diet. There have been many controlled experiments that have proven beyond doubt that domestic livestock benefit materially from the addition of certain minerals to those obtained from the normal forage. Chapline and Talbot (1926) have summarized the data on the use of common salt as a dietary supplement, and a tool for range management. Welch (1933), in a study of depraved appetites of range livestock in Montana, showed fairly conclusively that phosphorus hunger was the motivation.

There is some evidence to suggest that a cobalt lack exists in parts of north-central British Columbia and northern Alberta. Iodine is another element known to be deficient in parts of British Columbia to a degree sufficient to induce pathological changes in livestock.

Although the matter of diet may be the most important consideration in natural licks for game, there are other factors of no little importance concerned. There is a distinct possibility that the primary function of the use of licks is the alteration of the intestinal fauna and flora.

Several of the natural licks in Banff and Jasper National parks are focal points for much game activity. They foster the development of local concentrations of game and on this basis have some harmful influence on the game animals and upon the range. Some of the most sought after licks are surrounded by range that has been reduced to the ultimate stages of overuse through the long continued feeding of the game herds attracted to the vicinity. Another important result of the attraction that licks exert upon game is the exposure to predation that ensues. This is particularly noticeable in the case of mountain goat that in several parts of Jasper Park leave their chosen terrain on the crags and high grasslands and make their way through miles of forest to certain licks. During this passage they are inordinately subject to predation by black and grizzly bears and by mountain lions. Indeed, almost all goat kills found have been adjacent to licks. It seems probable also that the concentrations of game that develop at the licks are not unimportant in fostering the development of the high incidence of parasitism by nematodes characteristic of the bighorn sheep, mountain goat, and caribou particularly.

Five years of field work upon the big game of Jasper, Banff, Kootenay, and Yoho National parks in the Rocky Mountain region of western Alberta and eastern British Columbia have made possible a study of the game licks of these parks. The greater part of the area in question is situated in a broad belt of Paleozoic and early Mesozoic rocks that form the largest part of the Rocky Mountains east of the main divide in this latitude. These rocks are composed in large part of limestone and their weathering and erosion have led to the formation of many deep deposits of whitish soil frequently taking the form of steep,

naked, eroding cliffs and banks. In other parts of the park area mineral springs are numerous. Many of the white earth slopes are used as licks, and many of the mineral springs prove attractive to the native game animals.

In general the horned game, bighorn sheep and mountain goat, come almost exclusively to dry earth exposures, although sheep occassionally come to wet licks. The moose and caribou prefer wet, muck licks and mineral springs, mule deer and white-tailed deer come more frequently to the wet licks, but do use some of the dry licks; elk visit both types with almost equal freedom.

Game animals of the parks region have exhibited many instances of depraved appetites. At Columbia Ice Fields the bighorn flock regularly resorts to the ash dump where the animals eat the ash. During highway construction elk, sheep, and deer avidly lick the blasting powder residues. All forms make use of salt blocks whenever these are available, but occassionally evince a preference for the natural licks even in the presence of salt blocks. In one instance we even induced three bighorn to consume an entire three pound trout, by sprinkling the fish with salt. Bone-chewing is commonly resorted to, particularly by elk.

Game licks of the Rocky Mountain parks, quite apart from the possible importance of the licks in the nutrition and parasitism of the ungulates using them, offer so great an attraction for game that a knowledge of the nature and whereabouts of the most important of them greatly facilitates the finding of game under conditions ideal for close approach. Thus, for purposes of game study or photography, many licks provide ideal conditions. For this reason, as well as to facilitate further study of the licks here reported upon, the following account of some of the most important licks is given.

BANFF PARK

Goat Creek.—This lick is situated on a white earth cliff on the east side of the Spray River at its confluence with Goat Creek. It is used by goats.

Nine Mile Lick on Spray River.—A well-used lick bordering the Spray River fire road, nine miles from Banff. Used by goats. The lick consists of a stratum of gravel containing much light brown earth. This stratum is immediately below the darker brown, fine textured surface soil. Analyzed as sample 7.

Vermilion Lake.—At the north east corner of first Vermilion Lake, adjacent to the highway, is a deposit of wet soil of a pale gray appearance when dry. This is extensively used by bighorn sheep, also occasionally by moose and deer. This is the only wet lick found that was used by sheep. Analyzed as sample 9.

Six Mile Lick.—By the roadside, six miles west of Banff, is a small lick in pale brown earth, used by bighorn sheep.

Seven Mile Lick.—High on a limestone cliff seven miles west of Banff is a deposit of almost white earth much favoured by goats. Several pits large enough to accommodate full-grown goats have been eaten out of the soil. Analyzed as sample 8.

Sulphur Springs.—On the north bank of Panther River five miles below Windy Cabin there is a small sulphur spring that is apparently not used by game, but across the river and up a small tributary about three-quarters of a mile below the spring is a wet lick used by moose, deer, and elk. Apparently goats sometimes come to this lick.

Corners Lick.—On the north side of the Panther River at the junction of the Dormer and Panther rivers is a mud-bordered pond used by elk, moose, and deer.

Siffleur River.—One of the largest licks in Banff Park is situated adjacent to the trail about seven miles down the Siffleur River from the Pass of the same name. It is a deposit of

In attempting to interpret the results of the analyses we have made the assumption, in view of the stratigraphic uniformity of the region, that in each case the soil or water is being taken by game animals to satisfy the same need. This same assumption appears to have been made by Beath (Honess & Frost, 1942) in his interpretation of the analyses of five bighorn sheep licks in Wyoming, but in later discussions of other licks he was unable to apply it.

The animals themselves seem to be reasonably healthy during the period at which they seek the licks and thus offer no gross symptoms to assist in interpreting a mineral deficiency. However, if this assumption is substantially correct the sought after mineral will be among the small group of those common to all licks. An examination of Table 2 will reveal that sodium, magnesium, calcium, and iron were present in fairly large amounts in all samples, while copper, manganese, strontium, boron, and titanium were present largely as trace ele-

TABLE 1.—*Water soluble and acid soluble extracts in soils from 11 licks*

LICK NUMBER	WATER EXTRACT, PER CENT	ACID (1.0 N HCl EXTRACT, PER CENT
	Wet Licks	
1	.28	9.49
2	1.19	45.32
5	1.15	15.60
9	.16	17.97
14	.27	—
	Dry Licks	
3	.12	3.65
4	.57	30.52
6	.33	26.69
7	1.10	28.38
8	.45	18.52
10	.19	24.97

ments. Phosphorus and chlorine were also present in small amounts in all the samples (Table 3).

Magnesium and calcium are present in such abundance in the native rock of the regions that it is inconceivable that the vegetation is lacking in these elements. Similarly iron and titanium are so widespread in soils that it is doubtful if they are needed by the game in amounts greater than those supplied by the vegetation. There is little evidence of the essentiality of strontium and boron in ungulate nutrition.

Thus the field for selection would seem to be narrowed to phosphorus, sodium, chlorine, manganese, and copper. Pathologies in range cattle resulting from phosphorus deficiency have been reported by Scott (1929). Beath (*ibid.*) suggests that phosphorus is the important element in five sheep licks in Wyoming and is quoted as stating that .088 per cent of phosphorus in the water extract from a lick is a significant amount. In none of our samples is the percentage higher than .03 per cent. It seems reasonable to conclude, therefore, that this element is not the one sought after in these licks.

TABLE 2.—*Spectrographic analysis of water and acid soluble ash from 11 lick soils*

LICK NUMBER	ELEMENT																																	
	K		Cu		Na		Mg		Ca		Sr		Ba		B		Al		Si		Ti		Sn		Pb		U		Mn		Fe		Co		Ni	
	W	*A*	*W*	*A*	*W*	*A*	*W*	*A*	*W*	*A*	*W*	*A*	*W*	*A*	*W*	*A*	*W*	*A*	*W*	*A*	*W*	*A*	*W*	*A*	*W*	*A*	*W*	*A*	*W*	*A*	*W*	*A*	*W*	*A*
Wet Licks																																		
1	X	X	Tr	W	S	S	S	S	S	S	P	P	X	Tr	W	W	M	S	W	M	M	M	X	X	Tr	Tr	Tr	Tr	W	S	S	S	?	X	X	X
2	X	X	Tr	Tr	S	S	S	S	S	S	P	P	X	Tr	Tr	Tr	W	Tr	M	W	Tr	M	Tr	X	Tr	X	X	W	X	M	S	S	?	X	X	X
3	X	X	Tr	W	M	S	S	S	S	S	P	P	Tr	X	Tr	Tr	M	M	S	Tr	W	S	Tr	X	Tr	Tr	Tr	Tr	Tr	M	M	S	X	X	X	X
9	X	X	W	Tr	S	S	S	S	S	S	P	P	Tr	Tr	W	Tr	S	?	S	Tr	M	S	S	X	W	X	Tr	W	S	M	S	S	W	Tr	X	X
14	P	—	W	—	S	—	S	—	S	—	P	—	X	—	W	—	W	—	S	—	Tr	—	X	—	Tr	—	Tr	—	X	—	W	—	X	—	X	—
Dry Licks																																		
3	X	X	—	W	—	M	—	S	—	M	—	P	—	X	—	Tr	—	X	—	W	—	X	—	X	—	Tr	—	X	—	S	—	S	—	X	—	X
4	X	X	Tr	Tr	S	S	S	S	S	S	P	P	Tr	X	Tr	W	M	W	S	Tr	Tr	S	W	X	Tr	Tr	Tr	Tr	M	M	S	S	X	X	X	X
6	P	X	W	Tr	M	S	S	S	S	S	P	P	Tr	X	Tr	Tr	M	?	S	Tr	M	S	W	X	Tr	X	Tr	W	M	M	S	W	W	Tr	X	X
7	X	X	W	Tr	S	S	S	S	S	S	P	P	Tr	X	Tr	Tr	M	?	S	Tr	W	S	Tr	X	Tr	X	Tr	W	Tr	M	S	S	W	X	X	X
8	X	X	W	Tr	S	S	S	S	S	S	P	P	Tr	X	Tr	Tr	M	?	S	Tr	M	S	Tr	X	Tr	X	W	W	M	M	S	W	Tr	Tr	X	X
10	X	X	Tr	Tr	S	S	S	S	S	S	P	P	Tr	Tr	Tr	Tr	S	M	S	W	W	S	Tr	X	Tr	X	Tr	W	W	W	S	S	Tr	X	X	X

W = Ash from water extract.
A = Ash from 1.0 N HCl extract.
S = Strong (at least 0.50 per cent)
M = Medium (0.10–0.50 per cent).
W = Weak (0.01–0.10 per cent).
Tr = Trace (ca. 0.01 per cent).
P = Present.
X = Not Detected.

This conclusion is given greater weight by some other analyses made by us. In the belief that the comparison of the elements in a lick with the elements present in adjacent soils, that were not being sought after by game, would assist in the identification of the important item or items, such comparative analyses

TABLE 3.—*Quantitative analysis of some soluble lick constituents (All values in per cent air dry soil weight)*

LICK NUMBER	P		Ca		Cl	
	W	A	W	A	W	A
			Wet			
1	−	.01	.191	4.340	.021	—
2	+	.025	.035	1.176	.010	—
5	−	.030	.532	5.208	.008	—
9	−	.025	.126	5.375	.127	—
14	+	—	.083	—	.137	—
			Dry			
3	+	.022	.061	.329	.004	—
4	+	.022	.084	4.424	.004	—
6	+	.006	.722	4.704	.003	—
7	−	.008	.750	4.872	.002	—
8	−	.005	.181	4.477	.005	—
10	−	.011	.096	5.264	.005	—

W = Water solution. + = Trace detected
A = Acid solution. − = Not detected

TABLE 4.—*A comparison of chlorine and phosphorus content of lick soils and soils adjacent*

LOCATION	SOIL TYPE	EXTRACT	PHOSPHORUS, PER CENT AIR DRY WEIGHT	CHLORINE, PER CENT AIR DRY WEIGHT
Spray River	Lick soil	Aquaeous	trace	.008
		Acid	.01	.004
	Soil adjacent to lick	Aquaeous	trace	.012
		Acid	.01+	.007
Athabaska	Lick soil	Aquaeous	trace	trace
		Acid	.006	.003
	Soil adjacent to lick	Aquaeous	.01	trace
		Acid	.05	.002

were made on Athabaska Falls lick and Nine Mile lick on the Spray. At each place two samples of adjacent soil were analysed and the results compared with the constituents of the lick (Table 4). In one of these it was found that phosphorus was present in large amounts in the surface soil over the lick stratum and was relatively scarce in the lick itself. The source of the phosphorus in the surface soil is apparently the urine from the large numbers of animals that for years

have stood about under the trees above the licks. The smell of urine was strong when these soil samples were treated with the solvents.

Chlorine occurs in at least small amounts in all licks and is known to be attractive to game animals. Furthermore, the known increase in the demand for chlorine by cattle during the period when vegetation is succulent is in line with the observed period of heavy use of natural licks by game. However, it would be puzzling if the very small amounts of chlorine present in some of the licks, .137 to .002 per cent of air dry soil weight, in aqueous solutions, could prove so attractive to animals. In addition, our analyses outlined in Table 4 reveal that chlorine is no more abundant in the lick soils than it is in the adjacent non-lick soils. This in itself leads to the conclusion that chlorine is not the element sought after.

On the basis of spectrographic analysis copper and manganese are consistently present in the licks. As yet, standard chemical analyses for these elements have not been made. While deficiency diseases of livestock resulting from the lack of these elements are known, there are no reported instances of these in the American Northwest. Nevertheless, these two elements remain as possible sources of mineral lack, in the general diet, that can be supplied by the licks.

Our studies have not advanced the general knowledge of the function of natural licks in the physiology of wild ungulates much beyond that already obtaining. The results are inconclusive and, taken in conjunction with similar studies of smaller scope made elsewhere in North America, lead to the conclusions (1) that sodium chloride is not necessarily the essential element; (2) that phosphorus is not the essential element in these licks; (3) that trace elements may well be the critical constituents in these natural licks; and (4) that to arrive at conclusive results methods such as preference tests will probably be more productive than chemical analyses of the lick soils.

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SHADE OF PELAGE COLOR IN TWO POPULATIONS OF KANGAROO RATS AND REMARKS ON THE STATUS OF *DIPODOMYS MERRIAMI AMBIGUUS* MERRIAM

By W. Frank Blair

Large collections of four-toed kangaroo rats (*Dipodomys merriami*) were made by myself and my students in June and July, 1948, at two localities in Presidio County, Texas. These population samples afford an opportunity to compare the shade of pelage color in kangaroo rats occupying the pale-colored soils of the Rio Grande Valley with that of animals living on darker-colored soils a few miles from the river.

The two collecting stations were about twenty-five miles apart. One was on the Valentine Plain, just east of the Sierra Vieja Range and about ten miles west of Valentine, Texas, the other was adjacent to the Rio Grande and about five miles northwest of Porvenir, Texas. The two stations were, therefore, on opposite sides of the Sierra Vieja Range, which constitutes at least a partial barrier to the dispersal of this species.

Twenty-six adults were collected at the Porvenir station. A total of 136 specimens was collected at the Valentine station, but thirteen of these are excluded from my calculations because they were juveniles or were molting. The samples from the two stations are adequate for statistical analysis of variations in shade of pelage color.

Shade of pelage color was measured by means of a Photovolt photoelectric reflection meter, model 610, using a procedure similar to that described by Blair (1947). The only departure from this procedure was the use of a white porcelain block as a color standard instead of a magnesium carbonate block. A red filter was used for all of the readings. By the method used, with the instrument set on the porcelain block as 100, the galvanometer reading indicates the amount of light of the red-filter wave length reflected by the specimen in comparison with the amount reflected by the porcelain block. In other words, a reading of 35 for a specimen would mean that the specimen reflects 35 per cent as much light of the red wave length as does the porcelain block.

Color readings were made on samples of surface soil from the two stations. Five readings were made on each sample, and the average of the five readings was taken. The soil was stirred thoroughly between readings. The Valentine soil gave, with the red filter, an average reading of 27.0 reflection meter units. The Porvenir soil gave an average reading of 47.8 units. Since the magnitude of the reading is proportional to the paleness of the sample (i.e., the higher the reading the paler is the sample) it is obvious that the Rio Grande soil is much paler than the soil of the Valentine station. The Rio Grande soil is a loose, alluvial and wind-blown sand. The Valentine soil is also alluvium, derived by outwash from the rhyolitic Sierra Vieja.

Color readings on the kangaroo rats were made with the red filter on the mid-dorsal surface half way between the base of the tail and the base of the head of the round skins. The Valentine specimens averaged 17.42 $\pm$.16 reflection meter

units. The Porvenir specimens averaged 21.81 ±.38 units. The difference between the two means is 4.39 ±.41 reflection meter units, which is highly significant. This indicates, therefore, that the kangaroo rats from the pale soil of the Porvenir station are significantly paler than are those from the darker soil of the Valentine station. The method of color measurement here used is valuable in that it provides a quantitative measure of difference in shade of pelage color of the two populations. The color differences in the two populations are so great, however, that the two samples can be mixed and then separated easily as to locality by visual inspection alone.

The evidence of well-marked color differences between these populations, the pale-colored one on the pale soils adjacent to the Rio Grande and the dark-colored one on the darker soils away from the river, raises the question of the status of *Dipodomys merriami ambiguus* Merriam. This form, from El Paso, Texas, was originally described as *Dipodomys ambiguus* by Merriam (1890). Elliot (1901) reduced *ambiguus* to the rank of a subspecies of *merriami*, and it was so considered until Davis (1941) suggested that the subspecies *ambiguus* be considered a synonym of the subspecies *merriami*.

The present evidence indicates that the name *ambiguus* should be retained and applied to a population of pale-colored animals occupying the pale-colored sands of the Rio Grande Valley from El Paso to the Big Bend in Texas. The type series of *ambiguus* was collected, according to Bailey (1905), "on the sandy river bottoms just below El Paso." These animals are described by Bailey as being of a brighter, more golden color than *merriami*, and he indicates (*op. cit.*) that this color type extends along the Rio Grande Valley to Boquillas in the Big Bend. My evidence supports Bailey's observations.

The arguments offered by Davis (*op. cit.*) against recognition of *ambiguus* as a geographic race are primarily that: (1) there are no significant cranial differences or morphological differences other than in color between typical *ambiguus* and typical *merriami*, (2) the pale coloration of *ambiguus* represents an ecotype developed in response to edaphic conditions and that pale-colored individuals are found in the range of the race *merriami* and dark-colored individuals in the range of *ambiguus*. These objections do not seem to me to be valid.

In regard to Davis' first objection, I am in agreement that there seems to be no significant difference between the two forms in any character other than color. Slight clines in certain skeletal measurements are indicated in the range of the species *merriami*, but they do not correlate with the ranges of the two subspecies as here proposed. Morphological differences, other than color, are not necessary, however, for the recognition of subspecies. If they were it would be necessary to reduce to synonymy such obvious geographic races as *Perognathus apache gypsi* of the New Mexico White Sands and *Perognathus intermedius ater*, *Neotoma albigula melas*, and *Neotoma mexicana atrata* of the Tularosa Malpais.

Davis, in his objection that *ambiguus* represents an ecotype, overlooks the fact that a great many, if not a majority, of the described subspecies of mammals are probably ecotypes, each presumably representing selection by the environment toward a genotype that is most successful in that particular environment.

The question of recognition hinges not on whether or not an ecotype is involved, but on the extent of the area occupied by the ecotype and on the constancy of the ecotype over that area.

No dark-colored individuals have been reported from the range of *ambiguus* as here restricted. On the other hand, it is to be expected that pale-colored individuals do occur on local areas of pale-colored soil within the extensive range of the subspecies *merriami*. Subspecies are not uniform throughout their range. Statistical treatment of large samples of populations within the major ecologic trends represented by subspecies, by Dice (1940) and others, shows that geographic races are broken up into many more or less variable local populations. Formal subspecies are, therefore, in considerable part, the result of taxonomic expediency. If it serves to clarify the relationships and to indicate the variation within a species population to name a sub-population as a subspecies, then that population should be so named.

The naming of every local ecologic trend as a subspecies would lead to hopeless confusion and would be highly impractical. Any tendency in that direction is to be deplored. In the case at hand the area occupied by a comparatively uniform population of the *ambiguus* color type seems sufficiently extensive to warrant recognition as a subspecies. As I see it, the name *ambiguus* is applicable to the relatively pale-colored population of the Rio Grande Valley from El Paso to the Big Bend. The subspecies *merriami* is a variable, widely distributed population of predominantly dark-colored kangaroo rats that extends from California to western Texas. All kangaroo rats of the species *merriami* in western Texas are referred to the subspecies *merriami* except those in the valley of the Rio Grande.

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RESPONSE OF MALE DOGS TO URINE FROM FEMALES IN HEAT

By Frank A. Beach and Robert W. Gilmore

Dog owners who have kept adult females know that when a bitch comes into heat every male in the vicinity appears to be attracted to her dwelling place. So far as we know the oestrous female's attraction for the distant male has not been scientifically demonstrated, but in the course of an exploratory experiment we have obtained evidence suggesting that if such attraction does exist it might be due in part to the odor of her urine.

Six, healthy, young adult male dogs which had lived in our laboratory for half a year served as experimental subjects. All animals had previously been observed with receptive females and their capacity for mating behavior was known. Five were sexually active, but the sixth individual had never mated despite repeated opportunities to do so. In olfactory tests five dogs displayed discrimination between urine taken from a bitch in heat and urine from a non-oestrous female. The male that failed to mate also failed to respond differentially to the two types of urine.

Urine to be used as stimulus material was collected in some cases by catheterization and in others by forced emptying of the bladder. The reproductive status of the bitch was determined by mating tests or by inspection of the ovaries. Fresh material was refrigerated until use, and just before each testing period equal quantities of oestrous and non-oestrous urine were heated in a water bath to the dog's normal body temperature (101°F). Two clean cardboard boxes were partially filled with fresh sawdust and 10 cc. of stimulus material were sprinkled on the sawdust, oestrous urine in one box and non-oestrous in the other.

The two boxes were placed approximately fourteen feet apart on the freshly scrubbed floor of the testing enclosure and the male was allowed to explore the area for five minutes. Results were recorded in terms of total time spent examining each of the stimulus boxes. One trial was conducted each day until the statistical analysis (sign test and Student's t test) indicated that a significant difference had been established or that none could be expected with this particular method of testing. Various dogs received from eight to fourteen separate tests, and, as mentioned above, five animals showed a clear-cut "preference" for oestrous urine while the sixth dog exhibited none. Table 1 summarizes the results obtained during the first eight tests with the five positive cases.

Three facts are brought out by these figures. (1) Approximately half of the total test time was devoted to investigation of the stimulus boxes. (2) The box containing non-oestrous urine received considerable attention. (3) In every test more time was spent at the box of oestrous urine. These generalizations do not hold for every male in every test, but examination of the scores for each individual in all of his tests shows a difference in favor of oestrous urine which is significant at the one per cent level of confidence.

The absence of discriminatory behavior on the part of one male is difficult to explain. It may be significant that although this animal was sexually mature he

repeatedly failed to mate with receptive females. During the olfactory tests he often played with both stimulus boxes or paid little attention to either of them. It is possible that a positive reaction to oestrous urine is based upon learning and that actual mating experience is necessary before a male comes to associate this olfactory stimulus with sexual satisfaction. Additional experimentation would be necessary to establish the point.

If it is accepted that male dogs and, presumably, males of related species such as wolves and coyotes respond positively to oestrous urine it is easy to see how this attraction could operate to bring them into the vicinity of the female during her period of fertility. The hypothetical sequence of events is most obvious in connection with the behavior of wild animals or of domestic pets allowed to run

TABLE 1.—*Response of five male dogs to oestrous and non-oestrous urine*

TRIAL	TOTAL NUMBER OF SECONDS SPENT INVESTIGATING BOTH STIMULUS BOXES	PROPORTION OF TOTAL INVESTIGATION TIME SPENT AT BOX CONTAINING OESTROUS URINE
1	991	53 per cent
2	1002	58 per cent
3	839	60 per cent
4	1030	62 per cent
5	956	58 per cent
6	807	62 per cent
7	866	68 per cent
8	783	68 per cent

free. The bitch urinates more frequently when she is in heat and only a part of the bladder contents are expelled in each act of micturition. Accordingly in ranging over her territory the estrous female lays down a series of odor trails which converge upon her place of residence.

By following any one of these trails the male would eventually come into the female's presence. He would be less likely to join the nonreceptive female because, (1) she urinates infrequently and therefore her trail is less well marked, and (2) the odor of non-oestrous urine has less attraction for him.

This hypothesis is so obvious that it may well have been proposed by other writers, but it seems worth restating in view of our experimental findings.

Dr. L. F. Whitney's assistance in obtaining urine from females at the time of ovariectomy is gratefully acknowledged. This work was supported by the Committee for Research on Problems of Sex, National Research Council.

Yale University and Keyon College. Received October 23, 1948.

SHREDDED HORNS OF OXEN

By Erna Mohr

My 1948 paper (Natur und Volk, 78: 148–61) about "shredding horns of bovidae" had appeared in print prior to receipt of the volumes of the Journal of Mammalogy issued during the war years. In 1947 (Jour. Mamm., 28: 245–48), Francois Edmond-Blanc contributed an article about the newly discovered wild ox from Cambodia.

No discussion of his interesting arguments concerning the possible hybrid nature of the kouproh will be given here. However, I should point out that the photos of the points of the horn sheaths would allow one to make another interpretation than that given by Edmond-Blanc. Refer also to Urbain's (Mammalia, 1: 257–58, 1937) original description of *Bos sauveli* and photo (Pl. I, upper left, reprinted herewith).

In the wisent (European bison), among both bulls and cows, from the fourth year of life on the points of the new horns begin to pierce through the old sheath. At first the fringed edges of the old sheath are arranged like a collar below the points of the new horns. During the following months, up to two years, the fringes disappear and finally the edges of the old horn sheath grow progressively smooth. I have studied this phenomenon in a certain number of wisents of known age. Plate I, upper center and upper right, shows the left horn of the wisent bull "Puk." The photos were taken in July, 1937, and the bull was born August 24, 1933, hence the animal was four years old at the time of photographing.

Conditions are the same in the American bison, however I do not know at what time the new horn of this animal pierces through the old sheath, and I have no photos of my own to substantiate my point. However, in Martin S. Garretson's fine book, "The American Bison," on the plate facing page 37, there are photos of horn sheaths at different stages of life, showing practically the same conditions, but in contrast to the wisent, very often the steps in horn formation are permanent. Moreover, in Garretson's bison book, on the plate facing page 5 there is a photo of the wisent bull "Bernstein," taken December 3, 1929. In the photo this bull, born November 13, 1925, shows the beginning of piercing through the sheaths; the animal was at that time four years old.

In writing about the kouproh, Edmond-Blanc states (p. 247): "And a third characteristic and unique habit was that of turning up the soil with the horns and this apparently is the cause of the shredding of the horn sheath, leaving a very striking 'pom-pom' surrounding the tip of the horns of mature males; the sharp point of the horn projects from what appears as a kind of necklace. This phenomenon appears in males about the seventh or eighth year, according to the natives. . . . It has been suggested that when the animals turn up the soil with their horns that they are looking for roots, but I have examined these places and never found any roots. It appears possible, therefore, that they turn up the soil in this way in order to sharpen their horns and that in the process the horns are shredded. They continue to do this in order to keep the exposed point sharp."

Good observations are in part misinterpreted. Turning up the soil with their

PLATE I

Upper Left: Head of kouprob with fringed horns; after Urbain, 1937. Upper Center and Upper Right: Tip of left horn of wisent bull "Puk" when four years old. Lower Left: The wisent bull "Pliseh" ploughing the ground. Lower Right: The old wisent bull "Woburn" has worn away his horns to small stumps.

horns is not unique for the kouproh. Every mature bull performs in this way, including domestic ones; it appears they need to work off their surplus energies. Plate I, lower left, shows the wisent bull "Plisch" ploughing the soil with his horns. This turning up of the soil with the horns, often accompanied by pawing the ground with a forefoot, seems always to be the sign of some excitement, and has nothing to do with search for food. As an expression of its need to work off energy and perhaps to kill time, bulls not only plough the soil, but often push against trees, fences, rocks, etc., with their horns. Similarly, though less frequently, animals long confined in enclosures wear away their horns to short stumps, as shown by the old wisent bull "Woburn" owned by the London Zoo (Pl. I, lower right).

It is a misunderstanding to think that the points of the horns become sharpened by ploughing the soil; on the contrary, they become reduced to stumps in that manner. The principle is identical with that involved in plunging a knife again and again into the soil; each time it becomes more glittering, but also more blunt. Finally the fringes below the points of the horn sheaths become worn and the steps smoothed. As stated previously, in American bison, old animals very often have steps on the horn sheaths. This, I believe, may be explained by consideration of the shape of the bison horns. Generally, the two tips of their horns are nearer to each other than are their bases, and the animal is not able to turn its head enough to reach the ground and turn up the soil with the point of one horn. Only young animals should be able to do this. The wisent, like the kouproh, has widely spaced horns and is thus able to work over the ground with each horn individually and consequently wears away the fringes, the steps, and even the horn itself. The opinion that a bull turns up the soil for the express purpose of sharpening his horns appears to be without psychological basis. Actually the animal does not sharpen its horns in turning up the soil, instead they are reduced to stumps.

Hamburg 36, Zoologisches Museum, Jungiusstrasse 8. Received January 27, 1949.

Upper Left: Head of kouproh with fringed horns after Chapin, 1931. Upper Right: Head of bull "Puk" when four years old. Lower Left: The wisent bull "Plisch" ploughing the ground. Lower Right: The old wisent bull "Woburn" has worn away his horns to small stumps.

RABIES AS A POSSIBLE POPULATION CONTROL OF ARCTIC CANIDAE

By Ian McTaggart Cowan

The consideration of cyclic fluctuations in the numbers of the carnivorous fur-bearing mammals is usually approached from the aspect of food relations. It has been customary, for example, through the last two decades to state or imply a cause and effect relationship between the pulsations in the numbers of the varying hare and the more or less closely coincident fluctuations in the populations of several species of flesh-eating, fur-bearing mammals of the boreal forest region of North America. This relationship may sometimes exist, but there is an increasing body of evidence accumulating that by no means all of the cyclic declines in the carnivores are occasioned by food shortage.

It is the purpose of this short paper to put on record certain facts relative to a recent decline in the population of foxes (*Vulpes fulva*) in the Northwest Territories that was apparently brought about by an epidemic of a disease that, if not rabies, was very closely akin to this disease. Closely associated with the decimation of foxes there was an outbreak of rabies among wolves and sled dogs in the Northwest Territories.

Red fox numbers had been at a fairly high level over the western Arctic for several years preceding 1945. A graph of the red fox harvest in the Mackenzie Delta region is given on Figure 1 and is believed to be representative of the population of the region. It will be seen from this that a marked decline in the fox population took place in the winter 1944–45.

While in the Mackenzie Delta region in the summer of 1947 I attempted to gather details concerning this population decline. The decline had been most obvious to the local trappers and, one after another, almost every trapper questioned spoke of seeing the carcasses of foxes scattered about the Delta. Several men had seen ailing foxes and some had even witnessed the deaths of the animals. Three trappers reported seeming attacks upon themselves by foxes that were described as "crazy." In no case was there much purposefulness about the attacks.

In general the ailing foxes were reported to have run in an aimless fashion. If they encountered a willow thicket or some similar obstruction they persistently attempted to force their way through it with an apparently blind and purposeless frenzy. A number of carcasses discovered lay up against dense willow thickets as if they had died while blindly fighting the obstruction.

N. K. Lang of Aklavik found five dead foxes that winter, several others the next year, and reported a virtual absence of young foxes since the epidemic. He also reported that the outbreak began in the northern part of the Delta and spread southward. It took place while the varying hares were still numerous.

None of the dead foxes in the Mackenzie Delta were submitted to pathologists for examination, but the symptoms accompanying the epidemic, when taken in conjunction with the identification of rabies in an Arctic fox from Baker Lake and in wolf and sled dog remains from Frobisher Bay and Aklavik, N.W.T.

(Plummer, Jour. Comp. Med., 330–334, 1947), make it very probable that the foxes were afflicted with the same malady.

The timber wolf (*Canis lupus*) has been approaching a cyclic peak in population over much of northwestern North America during the last five years. It is not known whether the population of the western Arctic has suffered a sharp decline coincident with the fox decline, but certainly ailing wolves have been noticed, and their peculiar behaviour has been noteworthy. Three such instances have come to my attention.

FIG. 1.—Numbers of red fox (*Vulpes fulva*) marketed from the Mackenzie Delta between 1931 and 1945.

On January 22, 1947, at the winter reindeer herd camp on the east branch of the Mackenzie River through its delta, chief herder Mikel Polk and his son Nels Polk were on the river with a team of dogs and were accompanied by a small collie. A wolf appeared, rushed at the collie, and threw it into the air without inflicting any injury upon it. Nels Polk ran for the wolf, armed with an axe, whereupon the wolf turned upon him and he ran. Mikel Polk hurled his axe at the animal causing it to turn and run past the camp, where it was shot.

On February 2, 1947, a wolf came down to the Reindeer Station, ten miles up river from the site of the last attack. The animal fought with four sled dogs tethered near the camp and, though none of them bore obvious wounds from the encounter, there was blood on two of them. The wolf returned again the following

night and was shot. The dogs, one after another, sickened and died, deaths taking place on February 19, 20, 22, and March 13. Each dog in turn lost appetite and appeared to have a paralysis of the mandible and throat. At a later stage it vomited and frothed at the mouth. There was no excitement or tendency to bite. The acute stage of the disease lasted no more than 48 hours.

The head of this wolf and one of the dogs was submitted to the Division of Animal Pathology, Hull, Quebec, and was the subject of the report cited above. The animals were diagnosed as rabid.

The third attack was suffered by Warden Lee Post and his Indian guide. On February 4, Lee Post and his companion were traveling up the Mackenzie East Branch near Holmes Creek, just north of the two places mentioned above. They were traveling with two teams of dogs, the guide ahead and Post several yards behind riding his sled. One of his dogs had become lame and was trailing the rest of the outfit. There was brilliant moonlight.

The lame dog was heard to yelp and shortly afterward a wolf appeared on the back trail, gaining steadily. It made no sound, and as it came closer Post drew his axe and, as the animal came within reach, struck it on the head. The blow brought no sound from the wolf, nor any sign of anger, it merely swung off and loped past his team, overtook and passed the Indian, and attacked his lead dog. The Indian shot twice, but the wolf ran on up the trail and disappeared into the darkness. About two miles up river this, or another wolf, reappeared and ran parallel with the trail; two shots were fired without the wolf paying any attention to them.

The first dog was bitten in one hind leg, but the second dog showed no obvious wound. On February 24, roughly three weeks later, the first dog became highly excited and was put under observation. It died after four days of illness. On March 18 the second dog became excitable; on March 19 it began to throw itself when in harness, and was shot.

This account gives the details surrounding a known case of rabies in the timber wolf in the western Arctic with two other suspected cases in the same animal. It also records a coincident epidemic disease, strongly resembling rabies, among red foxes, an epidemic believed to be responsible for the recent cyclic decrease in the fox population.

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TWO METHODS FOR ESTIMATING POPULATION FROM TRAPPING RECORDS

By Don W. Hayne

Much of the small mammal trapping done at the present time is carried out in order to estimate the number of animals present. In the following discussion are presented two methods for interpretation of trapping results.

Small mammals are taken by two fundamentally different types of trapping, first, in experiments where the animals are marked and released into the population from which they were captured, and second, in experiments where the animals are removed as captured. The ecological advantages of mark-and-release trapping have been recognized by numerous investigators. Removal trapping, on the other hand, has practical advantages, and numerous sets of data from such studies are now available.

The two types of trapping records are discussed separately, one method for estimating the population being outlined for each of the two types. There are available for use several approaches based upon probability of capture, providing certain assumptions are made. The two methods here discussed have been applied with apparent success to numerous records of trapping the meadow vole (*Microtus pennsylvanicus pennsylvanicus* Ord) and to several other sets of data.

Appreciation is expressed to Professor Leo Katz of Michigan State College for helpful suggestions, and especially for pointing out the importance of assuming that the regression line passes through the origin in the method offered for use with mark-and-release trapping.

Mark-and-release trapping.—In this type of field technique, animals are captured alive, identified, commonly by marking in some manner, and then released again into the population from which they came. After a period of time, termed "trapping period" in this paper, the traps are tended again, and the unmarked animals are marked and released along with the animals which had previously been marked. This procedure has been extremely useful in the study of many phases of life history, but the interest in the present paper is only in its use in the estimation of the size of the population from which the traps are taking animals.

After trapping has been carried out for some time, the animals in the traps at each visit will consist in part of those previously handled and marked and in part of unmarked animals. Eventually, with no replacement of animals and with a trapping program of great enough intensity, all animals in the population might perhaps be marked, and the population size then be known from the total number of individuals handled during the census. However, when only a small proportion of the total number is taken during any one trapping period, and when marked animals are being replaced by unmarked individuals, then a completely marked population may be difficult and expensive to attain, and such an objective will often be impractical, if not impossible. Therefore, some method for estimating the population size after having marked only part of the animals is desired.

Lincoln Index method.—One such method has been in use for some time. Because of early application of the idea by F. C. Lincoln (1930) the method is

often termed the "Lincoln Index," although apparently much earlier use was made by Petersen in fisheries biology (Ricker, 1942; 1948). In following this technique, part of the animals in a population are marked. Samples are next captured to observe the proportion marked in the entire population, which now consists of a known number of marked animals along with an unknown number of unmarked. An estimate of the total number is computed by dividing the total number marked in the population by the proportion marked in the samples, under the assumption that the samples will estimate closely the proportion marked throughout the entire population. The estimates which are computed in this manner will refer to numbers present during the period of marking.

Use of the "Lincoln Index" method has been made in a number of small mammal studies, as by Allen (1938) with cottontails, Green and Evans (1940) with snowshoe hares, Southern (1940) with the European wild rabbit, McDougall (1946) in rat studies in Australia, and Fitch (1947; 1948) with cottontails and kangaroo rats. In these studies, the procedure has been to mark the animals in one series of trapping periods, and then to sample the population composed of marked and unmarked animals during a later period or series of periods. Of the workers quoted, Allen and also Southern marked animals which had been captured in traps, and then sampled the population by other methods, the one by shooting and the other by visual observation. This procedure tends to compensate for lack of uniformity in the first trapping (Ricker, 1948). The remaining workers used trapping both in the preliminary marking period and in the subsequent sampling period.

This approach to the estimation of a population is based upon a number of assumptions, chiefly, first, that the marked animals when released into the population will become distributed throughout and that further samples will take these marked animals with no greater or lesser probability of capture than the unmarked animals, and second, that no significant replacement of the population by unmarked animals will occur between the marking and the sampling periods. Mortality does not introduce a systematic error, so long as it happens in equal proportion among marked and unmarked animals, and does not result in the replacement of the dead animals by unmarked individuals from other sources.

An understanding of these assumptions appears essential to the intelligent use of the "Lincoln Index" method, and equally to use of the modification to be suggested in the present paper. In particular, it appears that in many small mammal populations the turnover is rapid, and individuals are being replaced constantly, either by dispersal with replacement by individuals from adjacent areas or by natural mortality with replacement by younger individuals growing to adult status. Under such conditions the lengthy separation of the preliminary marking period from the subsequent period when the population is sampled appears to result inevitably in an overestimation of the size of that population which was present during the marking period. Further, the assumption that all animals are exposed to a set of traps with the same individual probability of capture appears to the present author to be questionable, at least as applied to

populations of the meadow vole (*Microtus pennsylvanicus*). The practical importance of the error introduced by this latter difficulty is not clear in all cases, but the error is one of underestimating numbers present.

TABLE 1.—*Estimates of the numbers of adult female Microtus pennsylvanicus computed by the "Lincoln Index" method from records of trapping at East Lansing, Michigan, July 19–23, 1942. Each estimate is based upon captures made during two successive intervals, each of which is composed of one or more trapping periods, as specified. Traps were tended twice a day. "M" below indicates the morning catch, "E" the evening catch*

NUMBER OF PERIODS PER INTERVAL	PERIODS COMPOSING INTERVALS USED		NUMBER OF CAPTURES			ESTIMATE OF POPULATION
	First Interval	Second Interval	First Interval	Second Interval	Common to Both	
	(July)	(July)				
One	19E	20M	8	19	0	?
	20M	20E	19	10[1]	2	95
	20E	21M	10[1]	23	0	?
	21M	21E	23	9	0	?
	21E	22M	9	14	0	?
	22M	22E	14	9[1]	2	63
	22E	23M	9[1]	21	2	94
Two	19E, 20M	20E, 21M	27	33[1]	10	89
	20M, 20E	21M, 21E	27[1]	32	3	277
	20E, 21M	21E, 22M	33[1]	23	7	105
	21M, 21E	22M, 22E	32	21[1]	5	134
	21E, 22M	22E, 23M	23	28[1]	6	107
Three	19E, 20M, 20E	21M, 21E, 22M	35[1]	42[1]	13	110
	20M, 20E, 21M	21E, 22M, 22E	47[1]	29[1]	12	111
	20E, 21M, 21E	22M, 22E, 23M	42[1]	37[1]	15	101
Four	19E, 20M, 20E, 21M	21E, 22M, 22E, 23M	50[1]	45[1]	21	105

[1] One dead animal in this group.

It would seem that the shorter the period between the marking and the subsequent sampling, the less would be the effect of replacement within the population. Burt (1946) has suggested that a population estimate may be computed using the "Lincoln Index" method and the numbers of animals live-trapped during two consecutive days. Such a procedure should indeed minimize the effect of replacement. However, in experience with *Microtus*, trapping records from pairs of single trapping periods have at times shown considerable variability, apparently because relatively few of the animals handled are taken within any two consecu-

tive trapping periods, and because sometimes those which are so taken may contain a disproportionate number of animals with a high probability of capture, often termed "repeaters," or described as having a "trap habit." Such records tend to produce underestimates of the population.

A series of estimates computed from a field experiment is shown in Table 1. The data were recorded in a live-trapping experiment carried on at East Lansing, Michigan, between July 19 and August 4, 1942, with traps set in a rectangular grid at 60-foot intervals, covering 8.1 acres. Estimates in Table 1 are based only upon the period of July 19 through July 23. Capture records of only the adult female *Microtus pennsylvanicus* are shown here, and while the number of animals is not large, it is of about the same order often met in a practical problem. Estimates of population number have been computed according to the "Lincoln Index" method, and when based upon pairs of single trapping periods estimates may be computed for only three of the seven possible comparisons, because in four comparisons there were no animals which had been captured in both periods (Table 1). The three estimates computed seem too small in view of other observations.

Data from several trapping periods may be combined, and an estimate computed by comparison of two such combined periods. This has been done in the present example, and estimates based upon combinations formed from progressively more periods are shown in Table 1. As is to be expected, the estimates become less variable as the basis for their computation covers more time and more animals.

As longer and longer intervals of time are used, the estimates may be expected to increase where there is replacement of marked animals by those from neighboring populations. In the present example, when a number of estimates were based upon consecutive pairs of intervals, each ranging between four and eight days, the values computed lay between 124 and 132 animals. These estimates seem high compared with those given in Table 1, and those values to be given in Table 3.

In use of the "Lincoln Index" method, questions arise concerning, first, the proper length of the intervals to be compared, and second, a way of averaging a series of estimates similar to those shown in Table 1, where the estimates are not based upon independent sets of data. The approach suggested in the following section provides a partial answer to these questions.

Theory of proposed method.—The modified ratio method here proposed bases a population estimate upon the *increase* in the proportion marked which is observed in succeeding catches, as more animals become marked in the course of the experiment. Those persons familiar with use of "Lincoln Index" estimates may wish to view the method as one way of averaging all such estimates derived by comparison of the various paired sets of trapping data.

The change in proportion marked in successive catches may be related to the number of animals, the marking of which produces the change, in the following manner. After a certain number, x, of animals have been marked and released

into the population, P, from which they were trapped, the proportion of the population now marked (designated y) may be written as:

$$y = \frac{x}{P} \quad \text{or,} \quad y = \frac{1}{P}\,x, \ldots\ldots\ldots\ldots\ldots\ldots (1),$$

and this is the quantity which a sample drawn from the population will estimate. Each sampling, or each successive catch of animals as the marking progresses, will estimate the proportion marked at the different stages in the process. The equation above is that of a straight line passing through the origin of the coordinate system (point $x = 0$, $y = 0$), and the slope of the line is the reciprocal of the population size. This theoretical approach assumes a uniform population size with no replacement of marked animals for the period of the experiment, and further assumes a uniform probability of capture for all animals, since otherwise each catch would not sample the population in a representative manner. It is not clear as to how far any population may depart from strict conformity to these assumed standards and still permit the use of this, or of any other, ratio method as a practical tool.

In less mathematical terms, the discussion above may be restated thus: As marking of the animals progresses, the proportion of the population which is marked will increase. Marking one additional animal will cause the proportion marked to increase by a certain amount, and this increase is inversely proportional to the population number. After finding the average amount by which the marking of one further animal changes the proportion of the population which is marked, it is easy to estimate the population. For example, if the proportion marked as revealed by successive samples changes .01 (or 1 per cent) on the average for each animal marked, then the population evidently contains 100 animals. This population estimate is obtained by dividing 1 by .01. The mathematical term *slope* used above simply means the amount which the quantity y (proportion marked) changes with a change of one unit in x (number of animals previously marked).

Method of computing estimate.—The best fitting straight line passing through the origin may be fitted to the observed data, plotted as in Fig. 1, either by using some statistical method such as the one outlined here, or alternatively by drawing in the best fitting line by eye, especially if a field appraisal of the data is required. The slope of the computed or observed line is the reciprocal of the population number.

In computing an estimate the following formula will give the population number directly, without first obtaining the slope of the line and then its reciprocal:

$$P = \frac{\Sigma w x^2}{\Sigma w x y} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2),$$

where x, y, and P are as previously defined, w is the number of animals caught each time (marked and unmarked) and the symbol Σ represents the sum of the

specified values. This formula may readily be recognized as the inverted form of the usual expression for slope of a regression line passing through the origin (Snedecor, 1946). Schumacher and Eschmeyer (1943) have presented an identical method for computing an estimate of fish population number from records of netting, marking, and releasing.

Stated in words, the estimate is computed by dividing the sum of one series of products ($\Sigma\ w\ x^2$) by the sum of a different series of products ($\Sigma\ w\ x\ y$). The numerator ($\Sigma\ w\ x^2$) is obtained by adding the values, one from each trapping, obtained by multiplying the number caught by the square of the number previously marked and released (and assumed to be present in the population) before the trapping concerned. Likewise, the denominator is the sum of the values, one from each trapping, obtained by multiplying together three quantities, namely,

TABLE 2.—*Record of captures of adult female Microtus pennsylvanicus from July 19, P.M. through July 23, A.M. 1942, at East Lansing, Michigan, showing the progressive increase in the proportion of the catch previously handled in this experiment*

DATE OF CAPTURE	NUMBER OF CAPTURES		PROPORTION OF CATCH PREVIOUSLY HANDLED	TOTAL NUMBER PREVIOUSLY HANDLED
	New	Previously Handled		
			(*y*)	(*x*)
July 19, P.M.	8	0	.00	0
20, A.M.	19	0	.00	8
20, P.M.	8	2[1]	.20	27
21, A.M.	15	8	.35	34
21, P.M.	9	0	.00	49
22, A.M.	5	9	.64	58
22, P.M.	2	7[1]	.78	63
23, A.M.	8	13	.62	64

[1] One animal dead in this group.

the number of animals caught, the total previously marked, and the proportion of the catch observed to be marked.

Illustration of use of method.—As an illustration of the method, the population estimate will be computed from a set of field data. These figures were obtained in the same live-trapping experiment previously mentioned, carried on at East Lansing in 1942. The data here used relate only to adult female *Microtus pennsylvanicus*. Table 2 shows the trapping results for that part of the experiment beginning with the evening catch of July 19 and ending with the morning catch of July 23, the same period covered in Table 1.

During this experiment 74 individuals were captured, and the proportion of the animals marked in each catch, or sample of the population, rose from none at the first trapping to about two-thirds during the last periods, as shown in the fourth column of Table 2. When this proportion marked is plotted against the number of animals previously marked for each successive catch, then a distinct trend may be seen (Fig. 1). This relationship is described by Formula 1 under the assumptions outlined.

To estimate the number in this population by the suggested method requires two sums of products. For example, on the morning of July 22 (Table 2), the number captured (14) is multiplied by the square of the number marked and released previous to that time (58 squared, or 3364) to yield 47,096 for $w x^2$. The sum of corresponding values from all trappings ($\Sigma\, w x^2$) is 225,536. On the same morning the product of the number captured (14), the number previously marked and released (58), and the proportion marked in the catch (9/14, or .64) is 519.68, or $w x y$. The sum of all corresponding values ($\Sigma\, w x y$) is 2122.92. Dividing 225,536 by 2122.92 yields a value of 106 animals as the estimate.

Thus this method of examining the data indicates that the set of traps was drawing from a population of about 106 adult female mice, this estimate being made under the assumptions previously outlined. Although the traps occupied an area of 8.1 acres, the total area inhabited by the estimated 106 individuals is not known and therefore no estimate of population density may be made.

TABLE 3.—*Estimates of the numbers of adult female Microtus pennsylvanicus in contact with traps, East Lansing, Michigan, July 19 through August 4, 1942. The time has been divided arbitrarily into three periods. Figures in parentheses show actual numbers caught, not estimates*

SOURCE OF DATA	ESTIMATES FOR PERIODS		
	July 19, P.M.–23 A.M.	July 23 P.M.–29 A.M.	July 29 P.M.–Aug. 4 A.M.
All records	106	97	100
Records from July 19 P.M.–23 A.M.	(72)	47	49
Records from July 29 P.M.–Aug. 4 A.M.	54	54	(64)

The data from any other short period in the trapping experiment may be examined separately, as though this short period were an entire trapping experiment. The distinction here is between animals previously handled *in this period* and those not thus previously handled. Some type of sorting aid seems almost a necessity when examining the results of a large live-trapping experiment and punch cards of the McBee or other varieties are helpful. Suggestions for uses of punch cards have been made by Bailey, Casey, and Cox (1946).

Using the method outlined above, the trapping records of the experiment previously described have been examined in several different ways. The time from July 19 through August 4 has been broken arbitrarily into three consecutive periods, and the data from the first period have been used in the illustrative example discussed above. Table 3 summarizes the estimates based upon the entire experiment.

Using records for all captures, the consecutive estimates for the three periods are 106, 97, and 100, as shown on the first line of Table 3. Next, the 72 records for all animals captured and released in the first period were selected, and the estimates for each of the last two periods based upon these records were computed as 47 and 49 animals, respectively. These values are estimates of the number of animals out of the original 72 present during the period in question,

and suggest a considerable loss of individuals over a short time, a loss not reflected in the estimates of the total population present. Next, the 65 records of mice taken during the last period were considered similarly, yielding identical estimates of 54 and 54 animals present during the first and the second periods respectively. There is here a suggestion that animals taken during the last period were not all present during the first periods, but that some joined the population sometime thereafter.

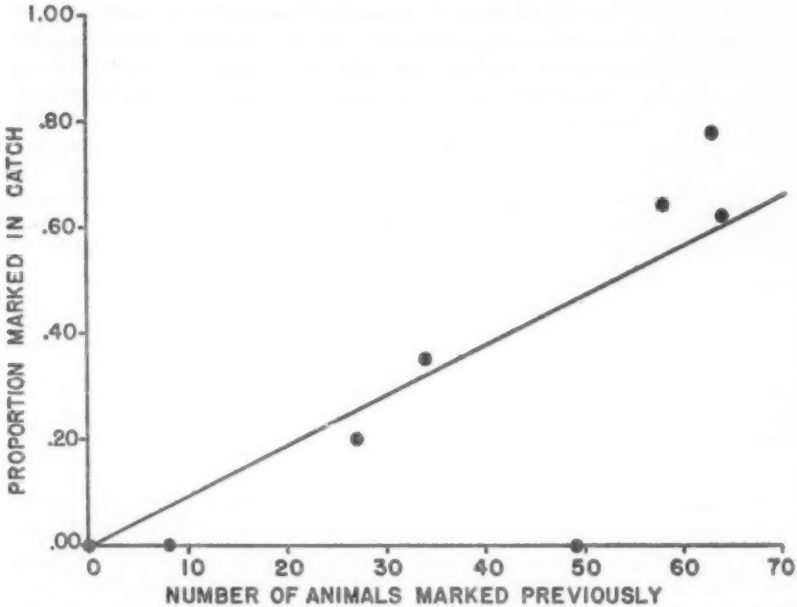

FIG. 1.—Increase in proportion of catch marked as more mice were marked in experiment at East Lansing, Michigan, July, 1942. Data relate only to adult female *Microtus pennsylvanicus*. The slope of a line fitted to the points shown is 0.0094, indicating a population of 106 animals.

One useful feature of this method is that it allows visual detection of at least some of the possible departures from theory as experienced in field data. If the trend of the data, when plotted as in Figure 1, is clearly not along a straight line, but follows a curve, then the theory is not adequate to describe the relationship.

There are probably numerous causes for a major or a minor disparity between the presumably very complex trapping behavior of a population of small mammals and the simple theory previously discussed (Formula 1). Among these, there are two factors which might produce roughly the same tendency in the data. Both variability throughout the animal population with respect to probability of

capture, and also steady replacement of individuals in the immediate population by animals from a large "outside" population should produce a tendency for the proportion marked in succeeding catches to increase, as more animals are marked, more rapidly at the beginning of an experiment than later. Thus the slope of the line would tend to decrease as the experiment proceeds, when data are plotted as in Figure 1.

Reliability of estimates.—Some approximation to the error of estimating the population is available in this method, since the standard error of the slope of a line may be computed, and probable limits of the slope determined (Snedecor, 1946). The reciprocals of the upper and lower probable limits of the slope will serve as limits for the population estimates. In the data used above as an example, for the estimate of 106 animals during the first period, based upon all records of capture of adult females, the limits within which similar estimates should fall 95 per cent of the time are 81 and 156 animals. These limits indicate that the estimates are far from precise.

One consequence of accepting this method of computing an error for the population estimate is that when the slope of the line does not differ significantly from zero then there exists no upper limit of the population estimate (reciprocal of zero). This seems a reasonable conclusion since, in order to base an estimate upon a change in proportion marked in succeeding catches, one surely must mark enough animals to produce a significant change in that proportion.

Removal trapping—theory of method.—Where the animals are removed as captured it is necessary to use a different approach from that previously discussed. In contrast, data from a mark-and-release experiment may be examined by either method, for by using only the records for animals newly captured, figures similar to those from removal trapping may be obtained.

The number of animals captured during any trapping period may be viewed as the product of two quantities, the first the probability of capture and the second the number of animals present at the beginning of the period. The probability of capture is assumed to be constant, describing the hazard in which any animal stands in relation to capture in the set of traps during one period. The number of animals present at the beginning of each period is assumed to be the original population minus the number of animals previously captured. Any great departure from these assumptions seems to invalidate this method for estimating the population number.

The number of animals taken during any trapping period may be represented by the following equation:

$$y = p(P - x) \quad \text{or,} \quad y = pP - px \ldots\ldots\ldots\ldots (3),$$

where P = original population,
p = the probability of capture,
y = number captured during the period,
x = number previously captured and removed before beginning of period in question.

In this equation, then, the slope is numerically equal to the probability of

capture. After the probability is determined by fitting a line to the data at hand, an estimate of P, the population number, may be computed, being the intercept of the line on the abscissa (x-axis), or the point at which the catch per period would become zero.

Repeating this brief discussion in a less mathematical form, the number of animals captured during any period is assumed to be proportional to the number present. The average difference between successive catches is related to the number of animals previously removed in a manner stated mathematically in the formula. As more animals are removed, the catch decreases, until it would reach zero when all animals had been captured. The field data are used to forecast this point of zero catch.

DeLury (1947) has recently suggested a method for estimating populations based upon a formula identical to that given above, for use with records of the

TABLE 4.—*Numbers of Microtus pennsylvanicus captured during three consecutive 24-hour periods, East Lansing, Michigan, June, 1948, by sex and age, with estimates of the numbers present*

	NUMBERS CAPTURED			
	Adult Males	Adult Females	All Adults	All Juveniles
June 13	5	8	13	3
June 14	1	2	3	1
June 15	1	1	2	1
Apparent probability of capture			0.71	0.54
Estimated population			18.1	5.4

progressive decrease in rate of capture of fish as the number in a population is reduced by fishing.

Examples of removal trapping.—To illustrate the method recommended here, two sets of data will be discussed, the first illustrating a situation where the method might be used, and the second showing an example where the method appears useless.

In June, 1948, meadow voles (*M. pennsylvanicus*) were trapped in a field near East Lansing, Michigan, being captured in a 475-foot line of traps which consisted of 20 sets of 3 traps each, the sets spaced 25 feet apart. The numbers of animals taken within each of the three consecutive 24-hour periods are shown in Table 4. Considering only the records for adult animals, when no animals had been previously captured, 13 were taken within one day. After the 13 had been removed, 3 were taken during the next day, and then, after 16 had been removed only 2 were taken during the following day. Figure 2 shows the progressive decrease in catch per day as animals were removed. A line has been fitted to the points in this figure. The slope of this line allows the probability of capture of adult animals to be estimated at .71. The population number may be estimated at 18, either by observing the intercept of the line on the x-axis in the figure or by computing this

quantity in the usual manner. Estimates based upon the records of juvenile animals are shown in Table 4.

The fact that the estimates of populations which were in contact with the traps were equal in this case to the total numbers of animals captured is not especially significant, except to indicate that the density of traps employed probably was sufficient to remove the population within three days. It seems here that the high probability of capture made it unlikely that an animal would escape the traps for three days in a row.

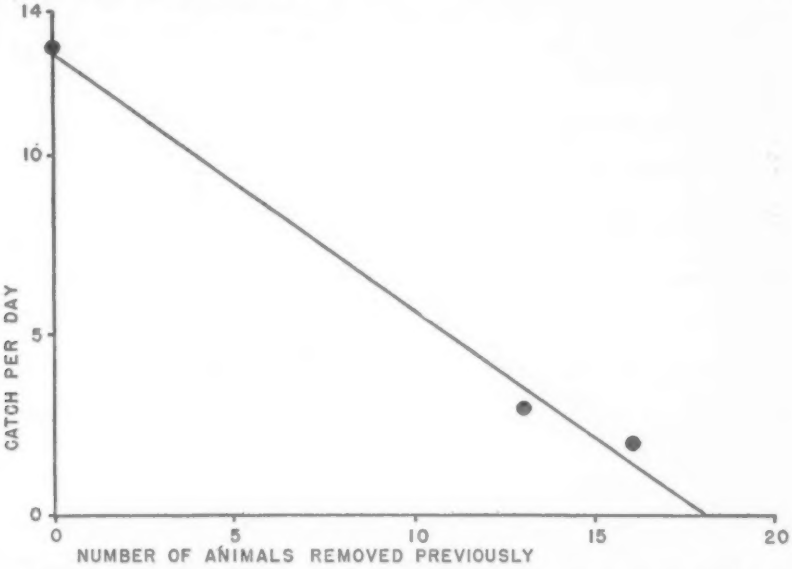

FIG. 2.—Progressive decrease in numbers of adult *Microtus pennsylvanicus* caught per day, as animals were removed from the area at East Lansing, Michigan, June, 1948. The slope of the line (-0.71) numerically equals the probability of capture, and indicates that about 7/10 of the animals present at the beginning of a period were trapped during that period.

The second set of data, shown in Figure 3, relates to the third period of the experiment discussed under the mark-and-release type of trapping in a previous section of this paper. These data describe the capture of adult female animals not previously handled within the period of July 29 through August 4. The catch per day of new animals behaved in an irregular manner, and did not decrease markedly as animals were captured. A hay field adjacent to the study area was mowed during this time, and from other data, not shown here, it seems possible that during the time from the second through the fourth days the probability of capture among animals considered to be residents decreased greatly, regaining the former value on the fifth day. During part of this time animals which were

classed as not residents behaved so as to suggest either an influx or an increased probability of capture. Whatever the details, such a situation would seem likely to give false results in an attempted census by removal trapping. Treating the mark-and-release data of this period by the first described method yields a value consistent with previous estimates (Table 3).

A complication, not compensated for here, is the fact that the probability of capture of any animal may be reduced as any trapping period progresses and other animals occupy various traps throughout the home range of the particular

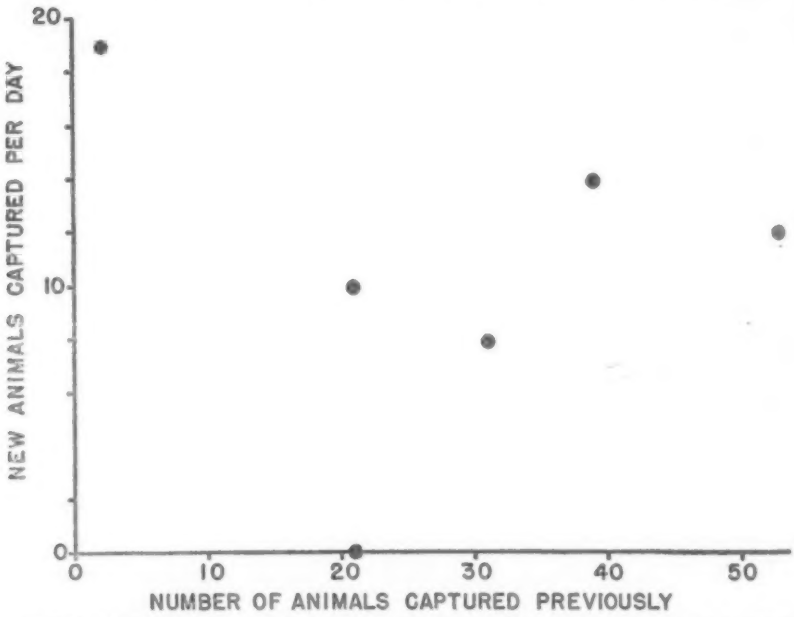

FIG. 3.—Numbers of new adult female *Microtus pennsylvanicus* caught per day as more animals were captured, East Lansing, Michigan, July and August, 1942.

animal considered. It might be necessary to employ a correction tending to increase the observed rate of capture, somewhat after the fashion of that used by Leslie and Davis (1939), when any considerable proportion of the traps are occupied.

Summary.—1. Data from mark-and-release experiments may be used for estimating the population present by following the increase of the proportion marked in samples drawn from the population as additional animals are marked. Compared with the second approach suggested, this method is not so severely upset by a day-to-day fluctuation in probability of capture throughout the whole population. An estimate of error is available.

2. Data from removal experiments may be used in estimating population by

following the decrease in the rate of capture as animals are withdrawn from the population. This approach depends upon the probability of capture remaining constant, and may be rendered useless by a change in this value.

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GROWTH AND BEHAVIOR OF A LITTER OF CAPTIVE LONG-TAILED WEASELS

By Glen C. Sanderson

The writer spent the summer of 1947 at the Delta Waterfowl Research Station, Delta, Manitoba. On June 25 a weasel was seen carrying a mouse (probably *Microtus*) along a sandy ridge road. The weasel was pursued for about 100 yards along the road, but it did not drop the mouse before escaping into a hole. That evening, number 1 jump traps were set at each entrance of the burrow; the next morning a female long-tailed weasel (*Mustela frenata longicauda*) was found dead in one of the traps. When a study skin was being prepared, it appeared that she had recently suckled young, and a hasty examination revealed at least three visible placental scars in each uterine horn. That evening, twenty-four hours after the traps had been set and twelve hours after the adult female was found dead in the trap, eight young weasels were dug out of the burrow. During this time the traps had remained set at both entrances, but the male was not caught. Although it is commonly believed that the male assists in bringing food to the young, in this case the male had apparently deserted the litter or did so when the traps were set.

Even though their eyes were fully open, the young were obviously too small and helpless to leave the burrow. They made no attempt to escape from the palm of my hand. One male, which was injured with the shovel as the litter was being dug out, had completely paralyzed hind legs; however, he was one of the larger weasels in the litter and seemed to be first in the "peck order." He was seen to take food from the others a number of times, but in spite of his paralysis none of the others took food from him. On the morning of June 26 only his skull remained. Weasels constantly chew one another in play, and it seems likely that a litter-mate had bitten one of his paralyzed legs and drawn blood. Thereupon the injured weasel ceased to be a playmate and became food. With the scent of warm blood, the rest of the litter probably could not be warded off.

Description of burrow.—The simple burrow was about three inches in diameter, with two chambers at a depth of twelve inches. One of these was empty, the other contained the young. The two surface-openings were but two feet apart and the entire burrow was no more than three feet long. Other weasels in this locality were found to use the extensive burrows of Richardson's ground squirrel (*Citellus r. richardsonii*) for dens.

Contrary to what Seton (Lives of game animals, pp. 612–618, 1929) and others have described, the meager nest material consisted entirely of finely chopped grass. There was no mouse hair present, no accumulation of fecal material, and no storehouse containing food. If there had been stored food it would probably have been eaten by the young after the capture of their mother.

Food.—A wide variety of foods were eaten: mice, shrews, and birds; skunk, weasel, and woodchuck carcasses; hamburger, ground liver, even bread and milk. The only food refused was a live Manitoba toad (*Bufo hemiophrys* Cope) and a live garter snake, although only the hind-legs of a frog were eaten. On two oc-

casions a weasel took a frog in its mouth but released it quickly, shook its head vigorously, and wiped its face in the sand as though the frog were extremely distasteful.

The kind of food eaten and the amount to the nearest gram was recorded. The surprisingly small amount of bones and feathers not eaten by the animals was collected and weighed, the weight being subtracted from the weight of the food offered in order to measure the food consumed daily.

The average amount eaten per weasel per day increased with the age of the animals, but not in proportion to the increase in body weight. From the fifth to the seventh week of age, they consumed approximately 22 per cent of their body weight per day; from the eighth to the tenth week (just before reaching mature size) they consumed approximately 24 per cent; but after reaching maturity they consumed only 18 per cent. When given all the food they would take in one day, they ate as much as 40 per cent of their body weight.

Behavior.—When first captured, the weasels slept in a mass in a small cardboard box. When they were handled it took from thirty seconds to a minute for them to wake and become active.

At first they were slow to kill live sparrows or small Norway rats because they were not strong enough to bite through the skull. However, from the first they attacked the base of the skull. With practice and as they became stronger, they became more efficient killers. They might have made the kill more quickly if one weasel had been alone in the cage free from interference by the others. Possibly in the wild the parents teach them to kill, but apparently it is not necessary for them to receive such training.

On July 4, when they were approximately six weeks of age, they developed the characteristic weasel odor. Only the day before, Dr. William Rowan had commented on their complete lack of odor. It was at this time that I found I could distinguish the one female of the litter from the others by her actions and smaller size. She was less aggressive and usually did not eat with the others. She continued to eat alone as long as the animals were kept together. When a live sparrow was put into the cage, the female weasel made the kill and for three or four minutes successfully fought off the six males by giving what may be called the "dominance squeak," and by twisting her body and pushing the others away with her rump and hind feet. Finally, several others took the sparrow away from her and she lost interest in it. My notes for July 31 record that the female was the most active and always bit me more when being weighed, but that she could not bite as hard as the others. At this time her actions and swollen vulva indicated the onset of heat. By August 2, when approximately nine weeks of age, she was clearly in heat. Wright (Jour. Mamm., 28: 343–352, 1947) says, "The young male remains sexually immature during this summer even though its litter mate sisters will reach a state of estrous and become impregnated by the adult males."

Growth rate.—The weasels were toe-clipped, weighed, and measured when captured (Table 1), and for sixteen days thereafter they were handled and weighed daily before being fed in the evening. For the next thirty-three days they were weighed less frequently, usually every other day, but never with more than

four days between weighings. After that, they were weighed once a week. Thus their growth was followed for sixty-three days, during which they were weighed thirty-five times.

TABLE 1.—*Weights and measurements of newly captured young weasels*

NUMBER	TOTAL LENGTH	TAIL	HIND FOOT	WEIGHT (GRAMS)
Males 1	275	88	39	116.5
2	285	89	38	113.6
3	265	83	37	101.4
4	280	89	35	107.8
5	275	88	38	109.4
6	270	84	39	100.4
7	270	81	38	104.4
Average male.....	274	86	37.7	107.6
Female.....	265	74	33	86.2
Mother.....	352	122	43	178.6

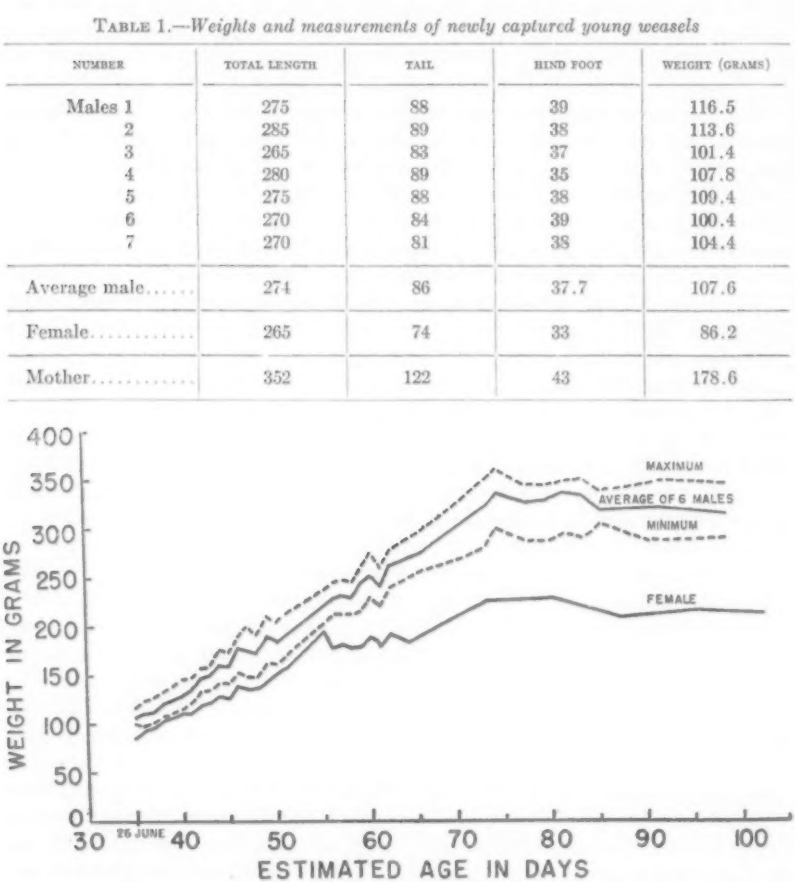

FIG. 1.—Rate of growth in a family of captive weasels—average, maximum, and minimum body weights of males in comparison with the weight of a female litter mate.

By using Hamilton's (Amer. Mid. Nat., 14: 289–344, 1933) data from another subspecies (*Mustela frenata noveboracensis*) it was estimated that these weasels were five weeks of age when captured. This would mean they were born about May 21. Hamilton (*ibid.*) found that he could distinguish sex by weight alone in *M. f. noveboracensis* by two weeks of age. His young males equalled their mother's weight at seven weeks, as did mine. The one female in the litter never

weighed as much as the lightest male (Fig. 1). Her rate of gain continued about the same as the males until July 16, when all were approximately eight weeks old. As noted above, she could be distinguished from the males by sight after about the first of July. At maturity she weighed 241 grams, 86 grams less than the average male at maturity.

At approximately ten weeks, the litter reached the peak of their growth and from then on their weight fluctuations showed no trend. The peak litter weight coincided with a period of hot weather in early August. When all weights were plotted separately, it was seen that all males reached their peak on the same day, August 3. The female was shipped to Dr. P. L. Wright at Montana State University on August 2, after she had come into heat. He continued to weigh her, but the data which he supplied showed no trend.

Wright (*loc. cit.*) found that young captive males reached mature size at approximately 81–83 days of age. He further reports that males in the wild do not reach mature size as soon as they do in captivity. In spite of this difference in the growth rates of captive and wild weasels, these data on the growth rates of captives are presented because it is rarely possible to obtain so complete a series of weights in either captive or wild weasels.

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Missouri Cooperative Wildlife Research Unit, Univ. of Missouri, Columbia, Missouri.
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NOTES ON LIVE-TRAPPING MINK

By Robert A. McCabe

Mustela vison letifera (Hollister) is the only species of mink occurring in Wisconsin. With a price on its head, and with the species nowhere in its range superabundant, opportunity and incentive for many kinds of study are lost.

This mink investigation was begun at the University of Wisconsin Arboretum in 1943 for the following reasons: (1) We felt there was a sufficient population on the refuge to warrant attempts at live-trapping; (2) the mink research could be done in conjunction with a pheasant project which was a larger, more laborious undertaking; (3) we hoped to learn something of the ecology and winter behavior of Arboretum mink; and (4) we wanted to test certain field techniques for working on wild mink. Four winters of trapping were completed by the winter of 1946–47.

The University Arboretum (Fig. 1) is an 1100-acre area located on the south shore of Lake Wingra about two miles from the campus at Madison, Wisconsin. The lowland or marsh areas comprise about 700 acres, bisected by a series of spring-fed creeks. In the east section of marsh are a group of artificial ponds. Some of these, through seepage holes in the banks, remain partly open during most of the winter. The marsh vegetation is chiefly perennial herbs such as goldenrod (*Solidago sp.*), aster (*Aster* sp.), sedge (*Carex* sp.), and smartweed (*Polygonum* sp.), and part of the area is grown to red osier dogwood (*Cornus stolonifera*), tartarian honeysuckle (*Lonicera tartarica*), elderberry (*Sambucus canadensis*), and willow (*Salix* sp.). In this habitat the mink work was undertaken.

Traps.—Our first attempt to catch mink was with a treadle-type box trap commonly used for catching rabbits (Gerstell, Penna. Game News, 7:11, 1937). It had a crude inside-lock arrangement, the details of which need not be elaborated. This trap was 24 x 7½ x 7½ inches and built with ¾-inch pine lumber. The entrance was six inches square and the back closed off, but with several ventilation openings. The first morning's set of these traps showed that four different mink had gotten in and *out* of seven of the eighteen traps set. Our lock was obviously inadequate.

The next lock arrangement was the attaching of a "cupboard catch" on the outside lower edge of the door, which as it fell allowed the catch to fall into a notch in the bottom-front of the trap. This locked the door securely. It could be opened by presssing on a spring mechanism on the upper part of the catch. Except during periods of rain or very high humidity these traps were efficient and successful. In damp weather, however, the sides of the trap and the door itself would warp despite the fact that the wood had been seasoned on the trap for over three years. If either or both the door and the corridor (formed by the sides and bottom) warped, the door would not fall properly or would stick along the sides and fail to lock.

The mink, unlike a rabbit, has the ability to lift an unlocked door. In one instance a mink chewed a hole through the locked wooden door. In many instances

a captured mink made an attempt to enlarge the ventilator holes in the rear of the trap. To save both the mink and equipment, all the backs of the traps were outfitted with ½-inch hardware cloth of the heaviest gauge. This hardware cloth was not chewed.

Warped traps were especially common and exasperating during the February thaws, the time during which the mink are very active. Our next step, therefore, was to remedy the "sticking door" difficulty.

In the summer of 1944, following the first winter's trapping, we improved the mink trap by building a metal door, a lock, and a corridor in which the door

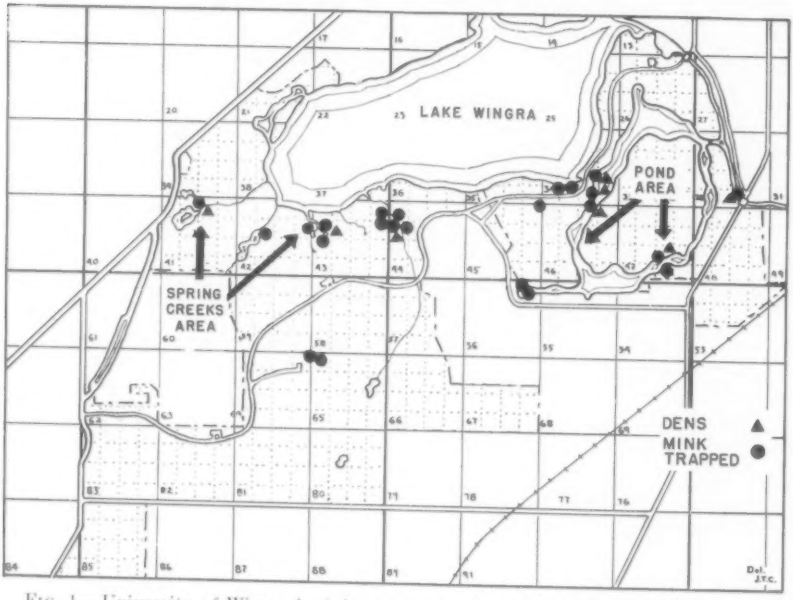

FIG. 1.—University of Wisconsin Arboretum, showing mink-trapping areas.

could fall, all as a single unit. This all-metal combination was nailed into the opening of the wooden rabbit trap (Pl. I). The metal door unit was so nailed that the wooden part of the trap was free to warp, without affecting the metal corridor or the door itself. Thus catch, door, or trap itself could not be plagued by moisture. Unfortunately these traps were not plagued by mink either.

Bait.—Baiting the traps was done with the utmost of care. Gloved rather than bare hands were used in moving and handling the traps. The bait was removed or placed into traps with a special stick and carried around the trap line in a bait pail that was indeed "special."

Rabbit, pheasant, duck, muskrat, squirrel, fish, and chicken heads and entrails were tried as bait. Rabbit, freshly killed, appeared to be most successful, particularly when the rabbit blood was dripped into the open traps. Baits were

changed whenever they dried or were stolen or eaten by shrews. No attempt was made to use live bait. The use of a commercial scent was tried during the 1946–47 winter, but no conclusions could be drawn as to its effectiveness. I personally believe the use of a good scent would increase trapping efficiency. We did try to

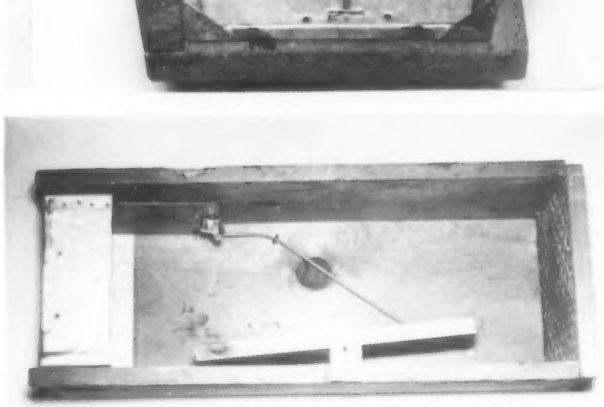

PLATE I

UPPER: Front view of mink trap showing metal door unit lock mechanism
LOWER: Side view of mink trap showing metal door when set

lure mink by placing in each trap several female scats gathered at a mink farm during the breeding season. Again the test run was so complicated with other variables that no conclusion could be drawn.

The traps were always set so that they were inclined slightly toward the front end. This facilitated a more rapid falling of the door and assured the locking of the catch. The traps were also placed so they could be checked from a distance

with or without field glasses. Thus the area around the trap was visited about once each week when the bait was changed.

Another attempt to improve trap efficiency was to close off the 6 x 6-inch trap entrance by hooking over it a board with a $2\frac{1}{2}$-inch circular hole. It was hoped that the darkened trap plus the inquisitive nature of the mink would entice the animals into the trap. This did not work.

Handling and marking.—Whenever a trap was sprung, it was examined on the spot; if it held a mink or weasel, the trap and its contents were removed to the Arboretum workshop. Here we could best remove the animal from the trap for handling. A grain sack was placed over the entrance after the trap had been turned *bottomside up*. The catch was released through the bag, allowing the door to fall open. A little persuasion through the back end of the trap with a stick forced the mink into the sack, and with gloved hand the end of the sack was closed. The sack was then placed on a table and as the animal moved about in the burlap cage its body shape could be noted and at the proper moment the animal was clasped behind the head. This operation was often accompanied by piercing screams from the mink and the shop was filled with the odor of musk. This sacking of the mink was best done by two men. Once the mink was firmly held (not choked), the sack could be rolled back on the holder's arm and the animal exposed. In this position it was sexed and marked. Sexing was a simple matter of examining the external genitalia.

Marking had no precedent so we used a combination of four methods. (1) Ear notching, which involved the cutting of thin V-shaped notches in the ear, was easily done, although the animal bled profusely. The main difficulty was that the healing of the ear obliterated the notch. In one instance, when a mink was caught the year after notching, the notches had almost grown closed. A further source of error could occur if ears should become naturally notched in fighting. (2) Numbered ear tags were attached by a washer-cotter key clasp. These were put on twelve mink. In four out of five recaptured in the same year, the ear tag remained intact and had been worn for a maximum of eight days. On a mink recaptured in the following winter, the tag had been pulled out and lost. Ear tagging might be feasible, but not with the tags we used. (3) The inside toe on a hind foot was clipped. This toe is small, easily clipped, does not impair the functioning of the foot, and heals rapidly. The toe-clipped animals were easily recognized as having been in the traps before, but no attempt was made to mark the animals individually by this method. Individuality was attained by our last method. (4) The ventral or belly pattern of the mink was diagrammed in a manner similar to that used in registering purebred Holstein cattle. At first this was done crudely, but later a gridded outline of a mink was prepared (Fig. 2) with the chin area enlarged and set to one side. The white chin patch is characteristic of the genus (Anthony, Field Book of N. Amer. Mammals, 1928: 108) and is often the only white area on the entire animal. No two specimens examined in the field could in any way be confused. The mink, like the leopard in the adage, is unable to change its spots. So it was without the slightest difficulty that we recognized a buck mink captured on March 9, 1945, as the same animal caught first on March

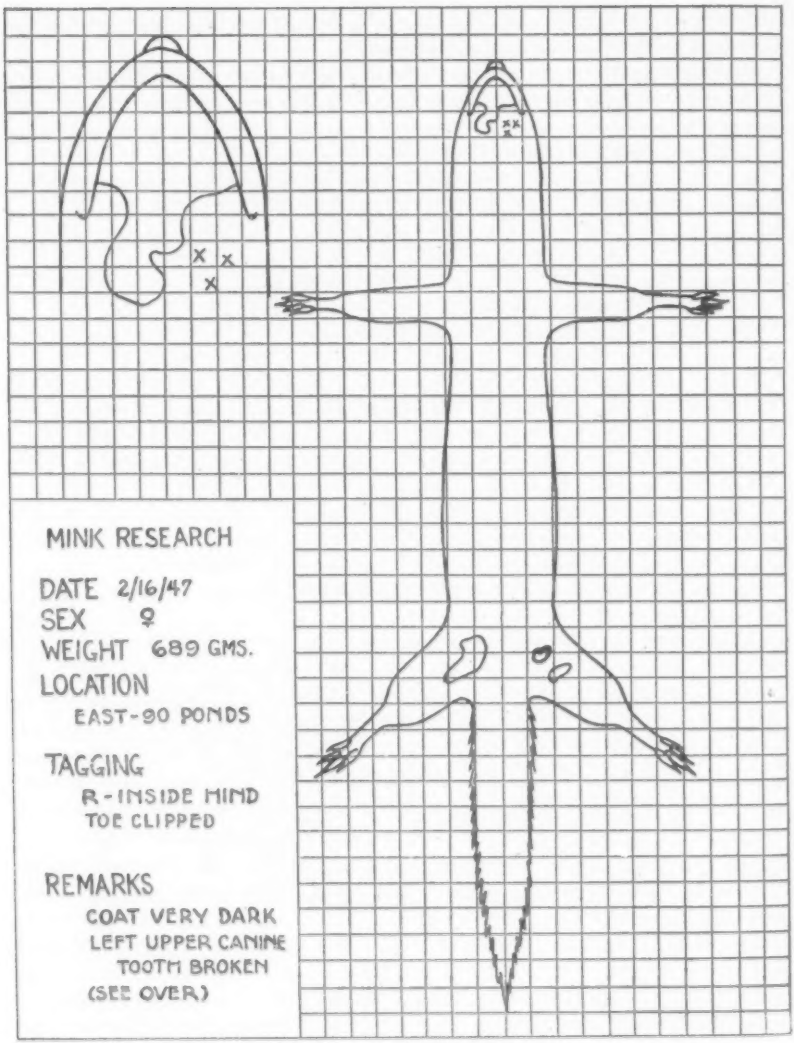

FIG. 2.—A sample marking of a mink belly pattern on the gridded outline.

31, 1944. This is perhaps the first "return" of its kind for wild mink and the only one we had in the study.

Trapping results.—The first winter's trapping (1944) yielded seventeen mink, five of which were repeats, that is, recatches in the same winter. In the subsequent three years we caught only six new mink, two of which later repeated four times; one mink was caught in two consecutive years (Table 1). Some of the possible

causes for this disparity in trapping success are also compared in the table. In the years of poor trapping the snow cover was both like and unlike the 1944 winter, which was the best for trapping results. Twice as many trap nights were run in the poor years and the probable food source varied from *worse* to *much better* between the good and the poor years. The relative abundance of food source was taken from field sign mostly in and around the corn-baited pheasant traps, and from animals caught and shot in a rabbit study carried on in these winters. Thus it seems that logical sources of discrepancy are ruled out.

The fact that there were less mink after 1944 (Table 1) was in my opinion due to excessive poaching and heavy trapping immediately outside of the refuge boundaries. The poaching is constantly combatted, but as of 1948 it is still a major difficulty.

On the basis of per cent captures of the estimated population, 1944 is still the best trapping year. The prime cause of failure in subsequent years I believe to

TABLE 1.—*Summary of mink trapping on the University of Wisconsin Arboretum*

YEAR	POPULATION ESTIMATES		SNOW COVER		CATCH		TRAP NIGHTS	FOOD SOURCE		
	♀	♂	Days	Max. (inches)	♀	♂		Rabbits	Mice	Shrews
1944	20	4	18	4	14	3	1070	med.	high	med.
1945	6	1	28	15	3	—	610	high	high	high
1946	8	2	28	3½	—	1	1330	high	low	very high
1947	7	2	28	13	2	—	465	high	low	low
1948	8	2	—	—	No trapping			high	low	low

be attributed to the galvanized metal door on the traps. While we had a mechanically perfect trap, there was apparently added to it a feature that repelled mink. Many traps containing the choicest of baits and located in the best of sites were by-passed day after day. The aversion of mink for metal is well known among fur trappers. For lack of time we have never been able to verify this with our part metal traps.

The population estimates were made from field observations and sign. There may be some error as to the sex of the mink, but I am reasonably certain that the total numbers are reliable (Table 1).

Life history notes.—The area covered by a male mink is known by most fur trappers to be extensive. The Arboretum observations on what I believe to be male mink tend to substantiate this. In each of the last three winters (1945, 1946, and 1947) a single male with a very large footprint and a long gait came in from the east, made long exploratory circles covering over a mile, and left in the direction from which he entered. Sometimes as much as a month later, the same kind of tracks appeared over much the same route. On only one occasion could I track the animal through the refuge. Whether this behavior is general, and whether the same animal was responsible in each case, I am not prepared to say. I do believe, however, that the mink habitat of the 1100-acre University Arboretum is too small to encompass the entire range of a male mink. The female appeared to be more confined in her movements. In a series of trapping repeats

(animals recaptured in a given year) the farthest distance any female moved was 400 yards (Table 2). The single male return (recapture in a year following marking) moved about a half mile.

All mink caught were released at the point of capture and were seldom held more than three hours in the handling process. By remaining quiet and motionless as the animal worked its way out of the untied sack, I was able to make many interesting observations during the release. If water was available the animal usually drank heavily and sometimes only a few feet from the release point. In one instance snow was eaten instead. Oftentimes the mink would lope off and disappear into a den, the locations of which are shown in Figure 1. One female mink, when released, began at once to hunt, grubbing under logs and scratching snow at *Microtus* burrows. With the aid of field glasses this animal was kept under observation for thirty-five minutes, but during this time she made no catches.

TABLE 2.—*Distances traveled by recaptured mink*

YEAR	SEX	DISTANCE TRAVELED YARDS	DAYS BETWEEN CATCHES
1944	♀	100	2
1944	♀	25	4
1944	♀	25	8
1944	♀	400	17
1944	♀	60	8
1945	♀	75	65
1945	♂[1]	880	356
1947	♀	30	4

[1] Return (banded one year, caught the year following).

The weights of nine females varied from 452 grams to 794 grams with an average weight of 574 grams. The five males averaged 1055 grams and ranged between 750 and 1570 grams.

In four winters' trapping, seventeen other species of mammals and two species of birds were caught in the mink sets. Two relatively uncommon mammals on the refuge, the least weasel (*Mustela rixosa*) and the house cat (*Felis*), were among those caught.

During the year (1944) in which the mink trapping was most successful, no weasels were caught and no sign observed on the trap line. The following winter when the mink trapping was poor and mink sign scarce, three male and three female weasels were caught. This apparent substitution of one mustelid for another in a given habitat is part of the ecological pattern. It seems logical that in a pyramid of animal numbers the larger of two carnivores occupying the same niche would tend to exclude or reduce the smaller.

Discussion.—The life history of the mink (*Mustela vison*) is perhaps as well known as that of any of our furbearers yet there is comparatively little material in print. The *Journal of Mammalogy* published nineteen volumes (1919–36) before a single mink paper appeared other than miscellaneous field notes. There is ample literature on steel trapping of mink and on the use of snares and deadfalls, but I found nothing on live-trapping these animals.

In the process of testing our various traps they had to be hauled into and out of the field several times, thus the time and physical effort required were considerable. This part of the operation is an important one and must be reckoned with in planning the time and money necessary to execute this kind of research project.

I believe that if we had continued to use our trap with the wooden door and metal catch, and accepted its drawbacks, the results would have been much better than those obtained by using the mechanically efficient all-metal-door trap.

We attempted to determine the earliest age at which the belly pattern identification could be used. To this end we drew patterns of fifty mink kits from five to thirty days old at the University-owned fur farm, but for reasons beyond our control no follow-up data could be obtained on these kits. This phase of the study is therefore still undone. The original thought was that this identification system might be useful to fur farmers in keeping records of valuable breeding animals. As far as we went, we found that within a litter the females tended to be more alike than did the males.

A similar system of pattern recording, I believe, could be done with photography, but our single attempt was not successful.

Summary.—An attempt was made to live-trap wild mink. Several variations of the treadle-type rabbit trap were used. The wooden door with a metal "cupboard" lock worked best. An all-metal door and lock attachment functioned best mechanically, but was unattractive for mink despite good baiting and trap locations.

Twenty-three mink, including repeats and returns, were captured and handled. Seventeen catches were made in the winter of 1944. The discrepancy in trapping success could not be correlated with food supply, bait, trap nights, or weather conditions. A lower population caused by poaching, and the use of metal door traps were perhaps the main causative factors.

Of several marking methods to identify individual mink, a single toe clipped plus a diagram of the belly pattern worked very well.

It appeared that weasels replaced mink in the Arboretum marsh habitat when the mink population was low.

The males weighed on an average 1055 grams, almost twice as much as the females (574 grams). The range of a male mink was larger than our study area (1100 acres) while the females moved very little and remained within the study area boundaries.

Acknowledgments.—Grateful appreciation is expressed to the late Aldo Leopold for advice and consultation; to the late Thomas Butzen for skillful construction of many of the trap mechanisms; to Frederick Greeley and Arnold S. Jackson, Jr., for running the trap line in 1945 and 1946, respectively; to Donald R. Thompson and James B. Hale for aid in the field work; to Joseph J. Hickey and Marie S. McCabe for critical reading of the manuscript.

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FIVE BATS NEW TO THE KNOWN FAUNA OF MEXICO

By Walter W. Dalquest and E. Raymond Hall

Among the specimens of mammals obtained in the state of Veracruz, Mexico, in 1946, 1947, and 1948 by one of us (Dalquest), for the University of Kansas Museum of Natural History, are bats of five kinds which seem not to have been previously recorded from the Republic of Mexico. Assistance with the field work is acknowledged from the University of Kansas Endowment Association.

Peropteryx macrotis macrotis (Wagner).—This species has been previously recorded from Brazil northward only as far as Guatemala.

Our specimens were obtained in the limestone hills bordering the upper part of the Rio Chalchijapa, a tributary to the Rio Coatzacoalcos, at 500 feet elevation, at a place 38 kilometers southeast of Jesus Carranza, at the lower edge of the Upper Humid Tropical Life-zone. There, on April 27, 1948, a small colony was found in a shallow recess in a limestone cliff. The recess was approximately four feet high, fifty feet long, and twenty feet above the river. The recess was shaded, but at midday was lighted as well as a room of the average house. The bats were clinging to the ceiling of this recess; when the collectors entered the bats took flight. Some of the bats entered a dark hole approximately twenty inches in diameter. The others flew to new perches in the recess where they clung to the rough, pitted ceiling. Eventually all of these were frightened into the one small hole. The hole proved to be the entrance to a small, room-like cave approximately six feet high and twenty-five feet in horizontal diameter, and was almost completely dark. An assistant entered the hole, following which a bat net was hung over the opening. The assistant frightened the bats, causing them to fly into the net; only one of the bats escaped. Ten were collected, including four males, a non-pregnant female, and five females with large embryos.

Later that same day a *Peropteryx macrotis* was the only bat found in a cave about three feet in diameter and 100 feet long, less than two kilometers from the recess first described. This specimen was a pregnant female. An *Artibeus jamaicensis jamaicensis* Leach was found at the mouth of this cave.

On April 28, two males with small testes were found in small caves in the limestone cliffs. One was alone. The other was in a cave with several *Balantiopteryx io* Thomas and one *Chrotopterus auritus* (Peters).

On April 30 the cave where the ten specimens were taken on April 27 was revisited. Only two bats, both of this species, were caught. Both were males with small testes.

Peropteryx kappleri Peters.—Previously this species was known from Ecuador and Dutch Guiana northward as far as Guatemala. *Peropteryx kappleri* seems to be the rarest of the six species of sac-winged bats thus far found in Veracruz.

Our four specimens were obtained in the same locality as the series of *Peropteryx macrotis*. At the base of a long limestone cliff, on April 30, 1948, a bat was seen to fly from a shaded area under a rock and enter the mouth of a small cave formed by fallen rocks. One person entered the cave while another guarded the mouth, which was about two feet high by a foot wide. The cave itself was approximately ten feet high and seven feet in diameter. Four bats were seen in the cave, with the aid of a flashlight. One was caught by hand. The other three flew out, where the guard caught one of them in his hand. The remaining two entered a similar but smaller cave thirty feet away. A net hung over the mouth of this cave caught the bats when they attempted to escape. All four were males with small testes.

Balantiopteryx io Thomas.—Previously this species was known only from a few localities in Guatemala.

On March 6, 1946, Mrs. Leora Forbes led the way to Grutas Atoyac. This cave is two kilometers east of Atoyac at about 1500 feet elevation. The mouth of the cave is midway down a steep limestone hill; the hill is situated between the railroad tracks and the Rio Atoyac. The

entrance is small, but the cave itself is more than 300 meters long. In the center of the floor of the cave, about 150 meters from the mouth, several old pits of excrement of vampire bats were found. Only a few vampires, *Desmodus rotundus murinus* (Wagner), were present. One *Balantiopteryx io* clung to the vertical wall of a narrow passage about eight feet from the floor near the end of the cave. In the last room of the cave approximately twenty *Balantiopteryx io* hung singly from the walls and ceiling. Only one of these was low enough to be caught by hand. Beneath each bat was a small pile, amounting to one or two thimbles full, of tiny black pellets of excrement. Larvae of beetles were actively feeding on these droppings. Many of the bats were in pit-like depressions in the ceiling. All were hanging head-down, many by only one foot. Thirteen animals of this lot were collected. Of the fourteen specimens saved from this cave, eight were males and six were non-pregnant females.

On April 25, 1948, a large population of this species was studied and specimens were obtained in a cave in a limestone cliff near the Rio Chalchijapa, 38 kilometers southeast of Jesus Carranza. The mouth of the cave is approximately thirty feet high, forty-five feet wide, and in a depression which is twenty feet above the river and seven feet below the base of the cliff. Inside, the height of the cave varies from twenty to fifty feet and the width from thirty to sixty feet. The cave, approximately 500 feet long, has a side passage about seventy-five feet long. In addition to *Balantiopteryx io*, the cave was inhabited by *Chilonycteris rubiginosa mexicana* Miller, *Artibeus jamaicensis jamaicensis*, and large numbers of *Myotis nigricans extremus* Miller and Allen.

Some *Balantiopteryx* were in crevices in masses of wavelike stalactites only thirty to fifty feet from the mouth of the cave, where there was sufficient daylight present for a person to see clearly the bats. In this area the bats were about twenty feet from the floor. The bats were most abundant approximately seventy-five feet from the mouth of the cave. Here, the height of the ceiling varies from twenty-five to fifty feet; most of the bats were clinging to that part of the ceiling which was only twenty-five to thirty-five feet above the floor. Only a few were seen as far as 100 feet, and only one was noted at a distance of more than 125 feet, from the mouth of the cave. In every instance the bats were hanging singly. Rarely were two bats within nine inches of one another. They preferred to hang from stalactites and the apices of pits and crevices, but some bats were on the open, flat ceiling. It was estimated that there were at least 500 bats present; possibly there were 1000. The amount of droppings beneath the roost was surprisingly small, considering the large number of bats.

In the vicinity of the cave mentioned above, *Balantiopteryx io* was very abundant. It was estimated that 1000 bats of this species were seen in other caves and crevices, and especially in the deep crevices at the tops of stalactite masses that hung from the cliffs.

Eighty-nine specimens were saved from this locality; 51 skins with skulls, 27 are alcoholics, 10 are skeletons, and one is a skin only. Of nearly 100 specimens captured and examined, only two were pregnant females. The remainder were males.

Chilonycteris personata Wagner.—Previously this species was known to range from Brazil to Guatemala. Strictly speaking, our specimens may not be the first to be recorded from Mexico in as much as Gerrit S. Miller, Jr. (Proc. Biol. Soc. Washington, vol. 15, p. 249, December 16, 1902) records "An overlooked specimen of *Chilonycteris psilotis*" from Tehuantepec, Mexico, obtained by Francis Sumichrast in 1858, and the species *Chilonycteris psilotis* Dobson was thought by Allen (Bull. Amer. Mus. Nat. Hist., vol. 30, pp. 264–265, December 2, 1911) to be a synonym of *personata*. If Allen was correct, the specimen taken by Sumichrast is the first recorded from Mexico, antedating our record by nearly 100 years.

The specimens here recorded were taken January 1 to January 8, 1948, in the Tuxtla Mountains at a place three kilometers east of San Andres Tuxtla, 1000 feet elevation. The specimens were mostly taken in a cave situated near the top of a basaltic cliff. The cave is a simple tunnel for some 200 feet. The entrance is triangular, approximately two meters on a side. Inside, the cave averages approximately six feet in height and ten feet in width. The maximum height was not measured, but was probably more than twelve feet. The floor of the cave is fairly level, but the cave is rather sinuous in the horizontal plane for some 200 feet. At this point it is offset vertically about eight feet, possibly as a result of a geologic

fault. Further progress on the original level is blocked by a wall of rock eight feet high, but above this the cave continues on a higher plane. This upper level of the cave is low and shallow, about ten feet wide by three feet high, and has numerous side rooms too shallow for a person to enter. The upper portion of the cave was never completely explored.

The wall of rock situated 200 feet from the entrance of the cave seemed to be a pagan shrine, for when the cave was first visited, and on every subsequent visit, bundles of freshly picked flowers were on ledges and in crevices in the rock wall. The lower part of the cave was inhabited by many bats, including *Chilonycteris rubiginosa mexicana*, *Glossophaga soricina leachii* (Gray), *Carollia perspicillata azteca* Saussure, *Desmodus rotundus murinus*, and *Natalus mexicanus* Miller. The upper level of the cave was inhabited by thousands of *Chilonycteris personata* and *Pteronotus davyi fulvus* (Thomas), with an occasional *Mormoops megalophylla megalophylla* Peters.

On visits to the cave, search was made first for rarities among the numerous bats which inhabited the lower level. Then, carefully removing the flowers which had been placed on the rock wall, one person would climb to the upper level. Directly above the rock wall was a small room approximately seven feet in height by twelve feet in length and width. The upper edge of the wall was a lip of rock twelve inches wide. On the other side was what appeared to be a whitish, level, stone floor, but closer inspection of what appeared to be a floor revealed only semi-liquid guano a foot or more in depth. The whitish effect resulted from the presence of millions of small, white maggots. Few bats were in this room. By wading through the guano a person could enter a narrow passage approximately ten feet in length. As soon as the beam of the flashlight entered the rooms on the other side of the passage there was a roar from the wings of thousands of bats which took flight in the confined space. The collector could enter these rooms and, with pistol or net, obtain large series of bats in a short time. It was impossible to remain long in the upper rooms because the temperature was high, probably more than 95° F., and the stench was almost unbearable. Millions of tiny black flies surrounded the collector, and especially the light. It was necessary to turn the light out for short periods since the flies actually obscured the beam of the light. The collector was nearly overcome twice by the heat and stench, and had to return to the rock wall on hands and knees to lie over the edge gasping the cool air of the lower cave, and when he reached the lower level he had to be helped to the mouth of the cave. The flowers always were replaced on the rock wall.

The collections obtained in the upper cave consisted of approximately half *Chilonycteris personata* and half *Pteronotus davyi fulvus*. On some days the catch would be predominantly of one species; on other days the other species would be most common; on still other days the two species would be taken in approximately equal numbers. In the cave, the *Chilonycteris* resembled small vampires in many respects. They ran swiftly with tightly folded wings and resembled large spiders. They perched on walls and in small holes and crevices, seemingly preferring to lie flat on horizontal or nearly horizontal surfaces of rock. Several times they were seen to jump across short spaces with tightly folded wings. They bit viciously when handled, but were unable to break the skin of a person's hand. They squeaked a great deal, both in flight and when at rest.

On the cold, rainy night of January 5, numerous small bats were flying over the surface of the lake (Laguna Encantada) near the cave. Two of these bats, both *Chilonycteris personata*, were shot. On subsequent nights, when the sky was clear, no bats were noted. Later in the night of January 5, the cave was visited to determine what species might be using it as a night resting place. The collectors entered the cave and stopped approximately thirty-five feet from the mouth. After a few moments bats began to fly past. A small, hoop net was swung swiftly down the probable line of flight of the bats entering the cave, and one or more bats were usually taken at each swing of the net. When the lights were turned on, to allow the captured animals to be placed in a bag, the bats would retreat. Sixty-eight bats were captured, consisting of fifty-six *Chilonycteris personata*, ten *Pteronotus davyi fulvus*, one *Carollia perspicillata azteca*, and one *Natalus mexicanus*.

The *Chilonycteris personata* usually had parasites, each bat averaging approximately

four winged flies and three large "stick-tight fleas." The *Pteronotus davyi fulvus* from the same cave had no "stick-tight fleas." Approximately twice as many males as females of *Chilonycteris personata* were captured, and none of the females was pregnant. Of 100 specimens saved, 69 were prepared as skins-with-skulls, 20 as alcoholics, 10 as skeletons, and one as a skull-only.

Micronycteris sylvestris (Thomas).—This rare bat was previously known only from a specimen from Costa Rica and one from Nicaragua.

Our specimens were obtained at 15 kilometers east-northeast of Tlacotepec, 1500 feet elevation, on December 11, 1947. The bats were found in a cave in a sandstone and conglomerate cliff. The cave was shallow, approximately six feet high by thirty feet wide by thirty feet deep, with a low, wide entrance. About twenty-five bats were present in the cave; thirteen were collected. No flashlight was available at the time, therefore, little was learned of the habits of this species.

Externally this species bears a striking resemblance to *Carollia perspicillata* in the common, gray phase, although the two species are members of different subfamilies. When freshly killed specimens of the two species were compared, *Micronycteris* was seen to differ in slightly smaller size, slightly slimmer body, larger ears, longer nose-leaf, and longer, more nearly naked muzzle. The differences were less apparent when the two were not side by side; the relatively naked muzzle was the most reliable field character.

Of the thirteen specimens collected, seven were non-pregnant females and six were males with small testes. Each of the bats had from three to five very small, winged, parasitic flies. Ten specimens were saved as skins-with-skulls, two as alcoholics, and one as a skeleton.

University of Kansas Museum of Natural History, Lawrence, Kansas. Received November 26, 1948.

GENERAL NOTES

RANGE-EXTENSION OF THE SWAMP RABBIT IN ILLINOIS

Recently accumulated evidence indicates that the swamp rabbit, *Sylvilagus aquaticus aquaticus* (Bachman), has extended its range northward in Illinois in the past forty years. Sherman (Jour. Mamm., 20: 259, 1939) reported an invasion of the swamp rabbit into South Carolina during the same period.

E. W. Nelson (N. Amer. Fauna, 29: 271, 273, 1909), in his monograph of the rabbits of North America, gave the range of the swamp rabbit in Illinois as ". . . wooded bottoms of Ohio and Mississippi rivers in southern Illinois . . ." and reported specimens from Olive Branch, Alexander County, and Reevesville, Johnson County.

In 1909 A. H. Howell (Proc. Biol. Soc. Washington, 22: 31, 1910) spent several weeks in southern Illinois, southeastern Missouri, and northwestern Kentucky and for the swamp rabbit reported: "Its upper limit in Missouri is a few miles south of Cape Girardeau. In Illinois it ranges slightly farther north in a narrow belt of swamp close to the Mississippi River, to within a few miles of Grand Tower. In the Ohio Valley it is found in the swamps on both sides of the river to a point about five miles below Golconda, Illinois. . . ."

Necker and Hatfield (Bull. Chicago Acad. Sci., 6(3): 56, 1941) reported a specimen from Herrin, Williamson County, Illinois. This specimen, in the Museum of Natural and Social Sciences, Southern Illinois University, Carbondale, Illinois, was shot by Philip E. Smith who informed me that the specimen was obtained six miles south of Herrin in the fall of 1938. Recently, Smith, now of Johns Hopkins University, has placed in the Museum of Natural History of the University of Kansas four additional skulls of the swamp rabbit from the following localities: Williamson County, 6 mi. S. Herrin, 2; 1 mi. S and 1 mi. W New Dennison, 1; and Jefferson County, 6 mi. N Sesser, 1. All of these were obtained in 1938.

Smith also interviewed several hunters in southern Illinois and has kindly given me per-

mission to publish the following excerpts from his notes. "In the fall of 1910, one swamp rabbit was killed at Parker [northeastern Johnson County], Illinois. . . . It was the first swamp rabbit that had ever been killed in that area as far as any of the old residents could remember. . . . In 1936, five were killed near Waltonville [Jefferson County] on Big Muddy

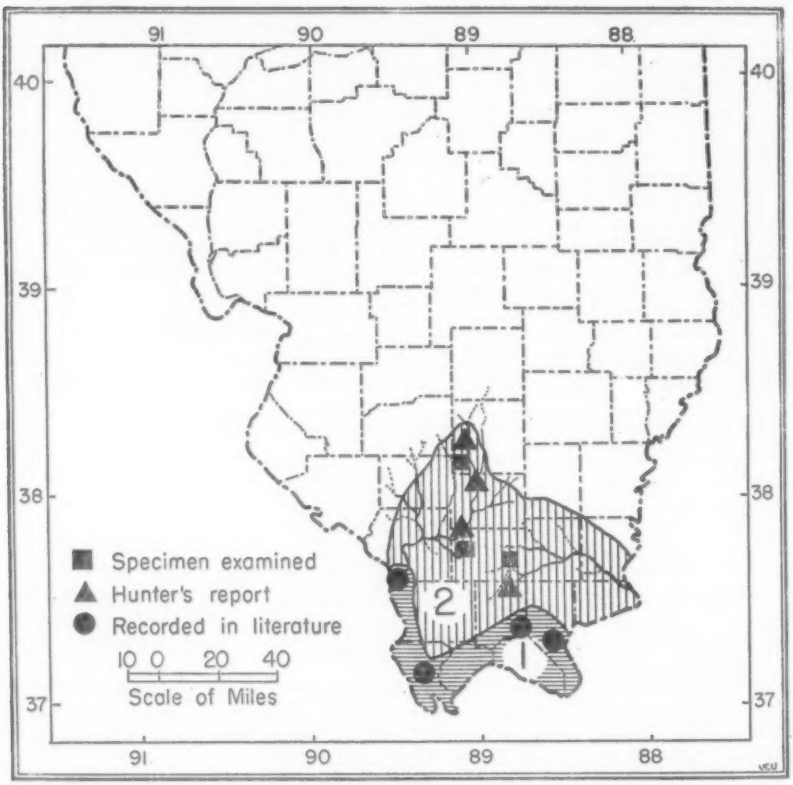

FIG. 1.—Map showing distribution of swamp rabbit (*Sylvilagus aquaticus*) in Illinois.

River. . . . In 1937, on Saline Creek between Marion and Creal Springs [Williamson County], Illinois (3 to 4 miles S of Marion), four were killed. . . . One [was taken] on Bit Muddy River —4 miles north of Herrin [Williamson County], Illinois. . . ."

Daniel Monroe Quillman, my grandfather, has hunted rabbits in the Big Muddy River bottomlands four miles east of Sesser, Franklin County, Illinois, almost every winter since boyhood (born 1868) until this writing (1947), but first observed swamp rabbits in that area in the winter of 1935–36. That winter, he recalls, three were killed by him. Swamp rabbits have been taken there almost every year since that time.

According to hunters' reports this rabbit is often found as far as a mile from, and when startled runs directly toward, the nearest swamp to escape an enemy. In a cypress swamp, in Johnson County, I have personally seen this rabbit take readily to water while attempt-

ing to escape an enemy, although it usually retreats into one of the thick brier patches adjacent to the swampy areas.

The swamp rabbit has probably moved up-river in the lowlands along the Big Muddy River from the lowlands of the Mississippi River and up the Ohio River Valley to Saline Creek and into its drainage basin. Its apparent range in 1909 and its probable range today are indicated on the map (Fig. 1). The extension of range here recorded is approximately 60 airline miles—Reevesville, Johnson County, to a point six miles north of Sesser *in* Jefferson County. More remarkable is the change in habitat since canebrakes and cypress swamps are to be found in Johnson County in the region of Reevesville, but are non-existent in the upper drainages of the Big Muddy River in Franklin and Jefferson counties.—E. Lendell Cockrum, *Museum of Natural History, University of Kansas, Lawrence, Kansas. Received February 11, 1949.*

THE EFFECT OF DEN FLOODING ON WOODCHUCKS

Comparatively few observations have been recorded concerning the effect of natural disasters on mammal populations. An exception is Leedy's note (Jour. Mamm., 30: 73, 1949) on woodchuck (*Marmota monax*) survival of a brush fire.

During the spring of 1948 while engaged in an ecological study at State College, Pennsylvania, I had the opportunity to make some observations on the effect of repeated flooding of twenty-four woodchuck burrows. The burrows, all in active use, were located in a quarter mile of creek bottom in fine sandy loam soil; all were within fifty feet of the main stream channel and all entrances were less than three feet above the normal summer water level. The burrows had from one to five entrance holes with an average of two, and were identified by numbered stakes.

The first and most severe flooding occurred the night of April 13 and the following day

Table 1.—*Den occupancy by woodchucks*

DEN NO.	APR. 8	APR. 14	APR. 21	APR. 29	MAY 12	MAY 13	MAY 14	MAY 20	MAY 25
1	in use	flooded	in use	in use	in use	flooded	disuse	in use	in use
2	"	"	"	"	"	"	"	disuse	"
3	"	"	"	"	"	"	"	in use	"
4	"	"	"	"	"	"	"	"	"
5	"	"	"	"	"	"	"	"	"
6	"	"	"	"	"	"	"	disuse	"
7	"	"	"	"	"	"	"	in use	"
8	"	"	"	"	"	"	flooded	disuse	disuse
9	"	"	"	flooded	"	"	"	"	in use
10	"	"	"	in use	"	"	disuse	"	disuse
14	"	"	"	"	"	"	flooded	in use	in use
15	"	"	"	"	"	"	disuse	"	"
16	"	"	"	"	"	"	"	disuse	disuse
17	"	"	"	"	"	"	"	"	"
18	"	"	"	"	"	"	"	"	"
19	"	"	"	"	"	"	"	"	in use
20	"	"	"	disuse	"	"	"	"	disuse
21	"	"	"	in use	"	"	"	"	in use
22	"	"	"	"	"	"	"	in use	"
23	"	"	"	"	"	"	"	"	"
24	"	"	"	"	"	"	"	"	"
25	"	"	"	"	"	"	"	disuse	disuse
26	"	"	"	"	"	"	"	in use	in use
27	"	"	"	"	"	"	"	"	"

when all burrows were under two to six feet of water for twenty-four to thirty-six hours. The stream rose rapidly during a heavy rain allowing little time for the escape of animals, and surrounding fields were flooded for several days. I covered the area in waders during the late afternoon of April 14 when the crest had passed and found no signs of any animals in the trees or on surrounding high ground. No dens could be located at that time.

By April 21 all dens were again in active use as evidenced by the freshly cleaned out entrances. Many had been buried under debris and it had been necessary for the woodchucks to remove large quantities of rubble and dirt.

Burrow No. 9 was flooded again on April 29 by a slight rise of the stream to the extent that water was rushing in one hole and out the other, however, by May 12 it showed signs of active use, as did all the other burrows.

On May 13 all burrows were again under a torrent of water for several hours. The afternoon of May 14, I again surveyed the entire area and found that three burrows were still flooded and the others showed no signs of reoccupancy. By May 20 twelve dens were again in use and by May 25 seventeen had been reoccupied. Thus only seven of the twenty-four burrows were abandoned after two severe floodings. It is interesting to note that burrow No. 9 which was flooded three times was not abandoned.

The history of the individual burrows during the successive flooding and reoccupancy is shown in Table 1.

No observations were made on breeding success or mortality underground, but it seems certain that many young woodchucks were drowned in the dens. There is no evidence that any adults were drowned; the abandonment of the seven burrows after the second flooding, which was not as sudden or as severe as the first, may or may not indicate mortality. All dens on surrounding high ground were also under observation and no new ones were located after either flood. There appeared to be a decided preference for the creek bottom as a den site, possibly explained by the ease of digging and the abundance of herbaceous vegetation, and repeated flooding did not seriously alter that preference.—WARREN W. CURRIER, *North Carolina Wildlife Resources Comm., Raleigh, N. C.* *Received March 16, 1949.*

SOME NOTES ON MOOSE PARASITES

During the fall of 1948 the following cases of parasitism in moose were examined. As comparatively little is known about the different moose parasites and the behavior of parasitized moose, the following notes on three moose shot during the hunting season may be of interest.

The liver, lungs, and heart of an adult moose shot at Hogarth, near Nipigon, on October 17 were examined. The hunter stated that he had found a cyst on the heart. Six hydatid cysts the size of pigeons eggs were removed from the lungs. The cysts contained the intermediate stage of the tapeworm, *Echinococcus granulosus*. The hunter stated that the moose was in a healthy condition, showed normal behavior and had considerable fat deposits.

The second moose was reported sick in the bush by a railroad employee from Shebandowan. He said that he had seen a large bull close to the railroad track where he had been working on a freight train together with several others. A day after the report came in, this moose was found about 200 yards from where it had been reported, still on the same side of the track. This location was an odd one, as the moose was hanging around a narrow stretch between the railroad track and a river, where it was constantly bothered by passing trains. To determine whether the moose was sickly or not, it was chased by the writer. It ran for a short distance, but did not cross either the railroad or the river, which it undoubtedly would have done under normal conditions. It appeared to drag its hind legs slightly.

This animal, because of its abnormal behavior, was shot. It showed no external signs of disease. No ectoparasites were found. The belly appeared to be distended, but this may have been because of large quantities of food stored in the stomachs.

An autopsy on the spot showed no apparent diseased condition of the organs except for

a great number of hydatid cysts of tapeworms in the lungs, some in the liver, and some in mesenteric tissue. One cyst was found on the lining of the heart and one on the lining of the abdominal cavity. The moose had practically no fat. The stomach was full of poorly digested food and weighed at least 80 pounds. An inspection of the mouth cavity showed no necrosis or discoloration. The incisors of the lower jaw were rather loose. Judging from the condition of the molars, the moose appeared to be 4–6 years old.

A further inspection in the laboratory by Dr. Allin showed the presence of numerous cysts throughout the liver tissue. There were also several cysts present in the cardiac muscle. The cysts in the heart musculature were generally about $\frac{1}{8}$ of the size of the ones present in the lungs. Microscopic examination showed an increased amount of fibrous connective tissue in the spleen. In the cardiac muscle fairly numerous round or oval patches enclosed by a thin capsule were found. These were identified by Dr. Fallis of the Ontario Research Foundation to be the fungus *Sarcocystis*. The cysts in the myocardium were *Taenia* sp., which could not be identified further as only sections were examined, and the ones in the lungs and liver were *Echinococcus granulosus*. This is apparently the first time that *Sarcocystis* has been reported from the moose. It might be possible that the described abnormal behavior of the animal was caused by these different parasites.

The third moose was shot by an American hunter on November 22 about five miles south of Ear Falls in Sioux Lookout Forest District. The liver was shipped to us because it appeared to be very mushy. Although a few hydatid cysts of *Echinococcus granulosus* were recovered, no pathological conditions could be noticed

In connection with the above it should be mentioned that the digestive tracts of most timber wolves from northwestern Ontario examined last winter contained tapeworms. *Echinococcus granulosus* was the most common species recovered, but tapeworms belonging to the genera *Taenia* and *Diphyllobothrium* were also found.—A. DE VOS AND A. E. ALLIN, *Ontario Dept. of Lands and Forests and Ontario Dept. of Health. Received February 26, 1949.*

LEAST WEASEL, PREY OF BARN OWL

During an examination of some pellets of the barn owl, *Tyto alba*, collected by R. J. Watson of Blacksburg, Virginia, the well-preserved skull and skeletal remains of an adult specimen of the least weasel, *Mustela rixosa allegheniensis* (Rhoads), were discovered.

These collections were made in March and April, 1948, near Blacksburg, Montgomery County, Virginia, at the base of a large white oak snag where barn owls have nested intermittently for several years. The nest snag is situated at the edge of an eighty-acre grove of virgin white oaks, *Quercus alba*, and overlooks a large expanse of cultivated land—pastures, meadows, and grain fields.

Previous collections of several hundred pellets at this nest indicate that these owls hunt exclusively in the open. Bones of *Microtus*, *Reithrodontomys*, and other typical field inhabitants predominate, while there are almost none of *Peromyscus*, a species abundant in the woods about the nest snag. The 1948 collection of twenty-two pellets and associated loose debris yielded remains of at least 67 *Microtus pennsylvanicus*, 4 *Mus musculus*, 2 *Blarina brevicauda*, 1 *Reithrodontomys humulis*, 1 *Rattus norvegicus*, 1 *Sylvilagus floridanus*, 1 *Peromyscus leucopus*, 1 *Mustela rixosa*, and 1 *Molothrus ater* (?). The weasel bones were contained in the same pellet with the bones of one *Microtus*. From this information it may be concluded that the weasel in all probability was captured by the owl in the cultivated land, possibly a considerable distance from thickets and woods.

This is the fourth specimen of *Mustela rixosa* taken at Blaksburg, and the fifth recorded for the State of Virginia. L. M. Llewellyn (Jour. Mamm., 23: 439–441, 1942) has listed the earlier specimens. The present note is prompted by the paucity of information regarding the distribution and habitat of *Mustela rixosa* in the southeastern United States, and by the unusual predator-prey relationship. Probably the least weasel is a very infrequent food of the barn owl.—CHARLES O. HANDLEY, JR., *Museum of Zoology, University of Michigan, Ann Arbor, Michigan. Received March 23, 1949.*

ROUGH-LEGGED HAWK FEEDS ON SHREWS

On January 3, 1949, a rough-legged hawk, *Buteo lagopus s.-johannis*, was brought to the Joseph Moore Museum at Earlham College, Indiana, for identification. This adult male in the light phase was shot on Christmas day three miles south and one mile west of Centerville, Indiana. At the time it was shot it was hovering characteristically over a haystack which was 3–4 years old. When the hawk's mouth was opened there appeared the tail and hind legs of a least shrew, *Cryptotis parva*. The crop was found to be full, and upon examination ten *Cryptotis parva* were discovered therein. To this observer's surprise the stomach also contained remnants of sixteen *Cryptotis parva* and one short-tailed shrew, *Blarina brevicauda*. The total found in the digestive system of this hawk was twenty-seven *Cryptotis parva* and one *Blarina brevicauda*.

Lyon, in his "Mammals of Indiana," (Amer. Mid. Nat., 17, 1936), says that *Cryptotis parva* is uncommon and that he himself took only one. The number of shrews taken by this hawk would indicate that these diminutive shrews are more abundant, at least locally, than the trapper might think.—James B. Cope, *Joseph Moore Museum, Richmond, Indiana. Received March 4, 1949.*

TUFTED TITMICE PULL HAIRS FROM LIVING MAMMALS

Chickadees and titmice line their nests with fur and hair of mammals, but they usually obtain this material from carcasses of wild animals or in farmyards where butchering has been done. A few accounts of the tufted titmouse (*Parus bicolor*) taking hair from living animals, including man, have been published in ornithological writings, but this habit does not appear to have been brought to the attention of mammalogists. Dr. A. C. Bent, in his Life Histories of North American Jays, Crows, and Titmice (U. S. Nat. Mus., Bull. 191: 397, 1946), cites an incident of this species pulling hair from the tail of a red squirrel lying on a branch, and another of a pair of titmice plucking fur from a woodchuck (*Marmota monax*) that had climbed a few feet into a tree. He also tells of two occasions when tufted titmice have busily snipped hair from the heads of human beings. Mr. Devereux Butcher, Executive Secretary of the National Parks Association, describes (quoted below) a similar observation he made near Washington, D. C. in the spring of 1944.

"Approaching a chestnut snag in the woods last spring, I looked up and saw three full-grown possums (*Didelphis v. virginiana*) peering down. It would have been a treat to see one, but three at a time was a show. I sat on the ground nearby to watch. The limbs of the chestnut had broken off and were hanging in the tops of surrounding smaller trees. Two of the possums were close together on one limb, while the third was alone on another. Remaining very still, they gave me the impression that they were trying to escape notice. But the possums were destined for trouble anyway, and this presently came to them in the form of a scolding titmouse. Flitting about, this titmouse became bold, always coming closer to the pair. Soon the bird alighted for an instant on an outstretched tail. Unthreatened, he eventually alighted on the animal's rump, pecking vigorously—or so I thought—and causing the possum to jump a little with pain. After a few moments I discovered that what was happening was that the titmouse was pulling out hair for nest lining. Upon acquiring a beakful, the bird disappeared. In a short while he returned for more, this time attacking the lone possum. Now he became so bold as to stand on the possum's back and uninterruptedly pull out hair for all he was worth."

It is to be noted that in all of these cases the mammal concerned was either naturally slow-moving, or else in a position where it was making little or no motion; while the human beings, of course, remained as still as possible during the time. It would be interesting to have similar observations recorded to determine how common this habit is, whether other species of birds engage in it, and what species of mammals are so treated.—Fred M. Packard, *National Parks Association, Washington, D. C. Received April 1, 1949.*

GESTATION PERIOD, YOUNG, AND MAXIMUM WEIGHT OF THE ISTHMIAN CAPYBARA, *HYDROCHOERUS ISTHMIUS* GOLDMAN

There is apparently no published information on either the gestation period or the newborn young of the isthmian capybara, *Hydrochoerus isthmius* Goldman. Asdell (Patterns of Mammalian Reproduction, Comstock Pub. Co., Ithaca, 1946) records 119–126 days to be the gestation period for *Hydrochoerus hydrochoeris* L. of South America, but gives no further information about the rodents of the family Hydrochoeridae.

For some years the Gorgas Memorial Laboratory has kept specimens of *H. isthmius* in captivity in connection with studies of equine trypanosomiasis to which the species is particularly susceptible. The animals take well to captivity, become docile, and feed well. They are permitted to graze at will during the day on the grass lawn of the laboratory grounds. At night they readily enter a large outdoor cage where they are locked up. In addition to the grass they secure by grazing, their diet is supplemented by generous supplies of fresh vegetables and fruits.

A young adult female capybara, weighing 33 pounds at the time of its receipt, July 20 1937, from El Real, Darien, Panama, came in heat during the last week of February, 1938, and was bred to a male. The last time she was observed to take the male was on March 1, 1938. She gave birth to three young on June 12, 1938. The gestation period thus is between 104 and 111 days, somewhat less than the 119–126 days recorded by Asdell for *H. hydrochoeris*. The mother and young were weighed on June 17, 1938, when the following weights were recorded: Mother, 45 lbs.; young (female), 2 lbs., 4 ozs.; young (female), 2 lbs., 11½ ozs.; young (female), 2 lbs., 15½ ozs.

This is the only instance of a birth of this species recorded at the Gorgas Memorial Laboratory. A female killed in Darien on August 27, 1930, weighed 62 pounds, and was apparently almost at full term; she had four unborn young (3 males and 1 female) with an average weight of 2 pounds.

Of some twenty capybaras received at the Gorgas Memorial Laboratory, the largest male weighed 58 pounds, largest female, 62 pounds.—HAROLD TRAPIDO, *Gorgas Memorial Laboratory, Apartado 1252, Panamá, R. de P.* *Received March 12, 1949.*

LONGEVITY IN THE LITTLE BROWN BAT, *MYOTIS LUCIFUGUS LUCIFUGUS*

A total of 1808 little brown bats, *Myotis lucifugus lucifugus* (LeConte), was banded and released in a summer colony at Southern Illinois University (formerly Southern Illinois Normal University), Carbondale, Jackson County, Illinois, in the summers of 1940–1942 (Cagle and Cockrum, Jour. Mamm., 24: 474–492, 1944). In 1945 Cagle (Jour. Mamm., 26: 307) reported the recovery of one specimen, a female, with a minimum age of five years. The recovery of four more specimens since Cagle's report appeared has added to our knowledge of the longevity in this subspecies.

A female, adult when banded on May 17, 1940, was recovered on January 13, 1945, by Paul Hilton in Rich's Cave, two miles east of Cobden, Union County, Illinois (14 miles south of the point of banding). This specimen was at least five and one-half years old when recovered.

A male, juvenal when banded on August 21, 1940, was recovered on September 23, 1946, by Wilburn Crain at a point four miles south of Gorham, Jackson County, Illinois (approximately 15 miles west of the point of banding). The known age of this specimen was six years.

A female, adult when banded on May 3, 1940, was one of fifty-two banded individuals taken from the colony at Carbondale and released on the day of banding at a point three miles north of Vandalia, Fayette County, Illinois (approximately 100 miles north of the point of capture, see Cagle and Cockrum, *loc. cit.*: 491). This female was recovered on May 10, 1945, by Mr. Jacob Hayes in Carbondale, Illinois. This individual was at least six years old.

A female, adult when banded on May 25, 1941, was recovered on May 27, 1948, by Julius Swayne at the point of banding. This individual was at least eight years old.

I am grateful to Dr. Fred R. Cagle, Department of Zoology, Tulane University of Louisiana, New Orleans, Louisiana, for making the original banding data available to me; to the United States Fish and Wildlife Service for furnishing the bands used and reporting the recoveries that came to their attention, and to Mr. Julius Swayne, Southern Illinois University, Carbondale, Illinois, for his co-operation in 1948 in checking the colony for banded individuals.—E. Lendell Cockrum, *Museum of Natural History, University of Kansas, Lawrence, Kansas.* *Received March 21, 1949.*

NOTES ON MAMMALS FROM ARIZONA, NEVADA, AND UTAH

The unusual demise of two bats in Big Cave, north of Yucca Forest, southeastern Sheep Mountains, Clark County, Nevada, seems worth recording. On July 27, 1945, while on a visit to the cave to observe bighorn sheep known to seek shelter there, Mr. A. V. S. Pulling and the writer discovered the bats hanging from the roof of the cave, attached to the leaves of a sandpaper plant, *Eucnide urens*. This species of plant was common in clumps on the nearby hillside and on the floor at the entrance of the cave, but only this one plant was growing downward from a crevice directly in the line of flight between another crevice (below which piles of bat guano lay) and the entrance. A mummified canyon bat (*Pipistrellus hesperus hesperus*) was fastened by the ventral surface, head up, to one of the large rough leaves. A little brown bat (*Myotis californicus stephensi*) hung head downward, fastened by the fur on the dorsum and the interfemoral membranes. The numerous small spines on these leaves held so firmly that the leaf split and part of it remained attached to the bat's fur instead of to the remainder of the plant when the animals were removed. The mummified specimens (Nos. 3115 and 3116) are now in the writer's collection.

A specimen of the leaf-nosed bat (*Macrotis californicus*) was taken from a tunnel at the Virgin Narrows northeast of Littlefield in Mohave County, Arizona, on March 10, 1945, by Ralph J. Hafen and Homer Christensen, two Dixie College students. Three bats were in a semidormant condition in a small hole near the roof, about 100 yards from the entrance of the abandoned tunnel on the south side of the Virgin River. One bat escaped by flying out of the tunnel, but the other two were captured and wrapped in a large handerchief. About two hours later, when presented to the writer, the *Macrotis* had killed and eaten part of the head, including contents of the cranium, of the other bat, a *Corynorhinus rafinesquii pallescens*. The female *Macrotis* contained no embryos. This seems to be a new record for the area, since the closest locality at which this species was formerly known was reported by Burt (Trans. San Diego Soc. Nat. Hist., 7: 393, 1934) from seven miles east of Las Vegas, Nevada.

How far do rodents carry seeds before burying or covering them? In Boxelder County, Utah, about two miles northwest of the old town of Promontory at about 4300 feet altitude, the lower flats and small valleys have been planted to winter, non-irrigated wheat. This has seemingly displaced, at least in part, the rodents which normally occupy such sagebrush flats so that they now occupy the edges of the fields and the hillsides where junipers and rocks are abundant. During a visit to the area August 31, 1946, the writer noticed that rodents had carried wheat from the field and buried it here and there through the pigmy conifer area. Each cache seemed to consist of about twenty-five to thirty kernels. The wheat crop had been harvested about six weeks previously and summer thunder showers had provided sufficient moisture for wheat germination so that the green grain tufts were now from 1½ to 2 inches high. The most distant tuft of growing grain was estimated, by pacing, to be 195 feet from the nearest wheat observed in the area. Cliff chipmunks, (*E. dorsalis utahensis*) may occur here. Overnight trapping obtained deer mice (*Peromyscus maniculatus sonoriensis*), pocket mice (*Perognathus parvus olivaceus*), and kangaroo rats (*Dipodomys ordii utahensis*). Probably kangaroo rats did the planting, since similar caches have been observed in other areas inhabited by these rodents—areas where the chipmunks did not occur.

When Goldman (Proc. Biol. Soc. Wash., 52: 34, 1939) named the pocket mouse, *Perognathus penicillatus seorsus* [= *sobrinus*], he gave the type locality as "sand flat along Virgin River, 7 miles above Bunkerville, Clark County, Nevada . . . collected by Vernon Bailey, May 9, 1891." Hall, in Mammals of Nevada (Univ. Calif. Press, p. 376, 1946), also lists Nevada as the type locality.

The type locality is either much less than seven miles above Bunkerville or, if seven miles as listed by Bailey in 1891, then it is in Mohave County, Arizona. Bunkerville, Nevada, is south of the Virgin River while Mesquite is north of this river. The distance along the highway (US 91), because of crossing the river and following square corners around farms, is much greater than the distance along the Virgin River at this point. The distance along the highway from Bunkerville to the Arizona State line northeast of Mesquite, checked with an automobile speedometer, was five miles. On October 2, 1943, and on later trips through the area, this same distance was recorded. Since the river crosses the state line south of the highway the distance along the river above Bunkerville to Arizona is not more than, but probably much less than, five miles. A sand flat along the Virgin River, seven miles above Bunkerville as recorded by Bailey, would thus not be in Nevada. The type locality of this pocket mouse thus must be presumed to be in Mohave County, Arizona. These mice are common on these Arizona sand flats along the river.

The kangaroo rat, *Dipodomys microps*, is a species nearly restricted to the Great Basin of Nevada and Utah. One of the few exceptions to this was noted in 1931 when Goldman named the race *D. m. leucotis* from six miles west of the Colorado River Bridge, Houserock Valley, on the north side of Marble Canyon of the Colorado River in Coconino County, Arizona. I obtained one adult of this species one-half mile east of this bridge on the south side of the Colorado, July 29, 1947. On the same night, three specimens were obtained one mile west of the bridge. Burrows of kangaroo rats were common on either side of the Colorado River. Since 1929, when the Navajo Bridge was completed, the species has evidently been able to cross the 834-foot-long span over the river and establish itself on the southern side.

How many species of small rodents live in or enter a kangaroo rat den? In an effort to answer this question, on September 23, 1944, on the Beaverdam slope, Washington County, Utah, thirty-six live traps were placed each at a different entrance to underground tunnels in one large kangaroo rat mound. It is not known whether all of these tunnels were interconnected, but from the nature of the mound it is assumed that most of them were. It was so arranged with soil and rocks that rodents leaving a tunnel would enter a metal box trap. The next morning the traps contained one kangaroo rat (*Dipodomys microps woodburyi*), one grasshopper mouse (*Onychomys torridus longicaudus*), and two pocket mice (*Perognathus formosus mohavensis*). Some of the tunnels were too small for a kangaroo rat, but the small animals were in traps at the entrances of the large burrows. Since *D. microps* in this area is known to have large seed caches in their burrows at this time of year, were the pocket mice and the grasshopper mouse in search of food? *Dipodomys merriami* pilfers food from the stores of *D. spectabilis* in Arizona (Vorhies & Taylor, U. S. Dept. Agric. Bull. 109:33, 1922).—Ross Hardy, *Weber College, Ogden, Utah. Received March 12, 1949.*

RECENT RECORDS OF COYOTES IN PENNSYLVANIA AND NEW JERSEY

On January 10, 1939, a dog-like animal was shot by one George Shaffer in Sheshequin Township, Bradford County, Pennsylvania, and shipped in the flesh to the Pennsylvania Game Commission at Harrisburg. They in turn forwarded it to the Academy of Natural Sciences of Philadelphia where the late Wharton Huber, Curator of Mammals, identified it as a coyote (*Canis latrans*). I then prepared the skin, skull, and skeleton for the museum's mammal collection where the specimen received catalogue number 20071. The animal was a male weighing 36 pounds. Measurements are as follows: total length, 1282 mm.; tail, 356; hind foot, 202; ear from crown, 122; ear from notch, 110.

This large coyote was in prime coat and fine physical condition. The long hairs of the back are mixed buffy and gray, heavily tipped with black. The muzzle, backs of the ears,

and outer sides of all four legs are rich ochraceous-buff. There is a narrow black stripe down the front of each foreleg and a black spot near the base of the tail. The underparts are whitish. I believe it to be an example of the typical race, *Canis latrans latrans*.

A very different appearing coyote was trapped in the Chestnut Hill section of Philadelphia, Pennsylvania, by Randal Morgan 3rd. on November 5, 1942. It was a male, pale in color, and quite small; it weighed only 18½ pounds. The general coloration above is buffy mixed with pale brown and the longer hairs are sparsely tipped with brownish black. The muzzle, backs of the ears, nape, and outer sides of the legs are buff. There are faint black markings on the forelegs and a black spot near the base of the tail. The underparts are white. The measurements are: total length 1091 mm.; tail, 330; hind foot, 178; ear from crown, 127; ear from notch, 108. The skin of this animal is no. 20630 in the Academy's mammal collection. It appears to be an example of the desert coyote, *Canis latrans estor*.

Much local publicity was given a large male coyote killed by deer hunters near Fishing Creek, Cape May County, New Jersey, on December 13, 1948. It was first identified by a New Jersey State Game Warden as a gray wolf, a species extinct in that state for more than a century. I am indebted to A. D. and A. R. Stasche, Philadelphia taxidermists, for the opportunity of examining this animal in their studios where it was being mounted for Frank Menz of Millville, New Jersey. This coyote weighed 36½ pounds and measured as follows: total length, 1281 mm.; tail, 390; hind foot, 219; ear from crown, 118; ear from notch, 108. In coloration it agrees closely with the one from Sheshequin. The guard hairs of the back are heavily tipped with black. The ears and brush are tipped with black. The outer sides of all four legs are rich ochraceous-buff. There are black stripes on the fronts of the forelegs and the typical black spot occurs near the base of the tail. Apparently the animal was caught in a trap at one time for the third and fourth toes of the left forefoot are missing. I have assigned it to the typical race, *Canis latrans latrans*.

Wild coyotes have been collected in almost every eastern state. Naturalists have long felt that these animals did not make their way east under their own power, but rather were escaped or released "pets." The records of the Philadelphia Zoo would seem to corroborate this. On December 11, 1930, the zoo received a female coyote from an individual in Cape May, New Jersey. A male was presented from Pleasantville, New Jersey, on May 7, 1936. Two from a litter of three born at the zoo on April 28, 1938, were given to a person in Bridgeton, New Jersey. Four young ones were presented to the zoo by a man in Trenton, New Jersey, on June 4, 1942. A coyote still living at the zoo was captured on July 26, 1946, in a store in Manayunk, Philadelphia, where it had taken refuge. Only the last example was actually at large, but the records certainly indicate that coyotes are commonly kept as pets. A certain percentage of these could be expected to escape, and some of the rest might conceivably be released deliberately. Owners who have no scruples about loosing undesirable predators in settled districts may readily do so when they tire of them or the beasts become vicious upon maturity.—Frederick A. Ulmer, Jr., *Zoological Society of Philadelphia, Philadelphia, Pa.* *Received March 25, 1949.*

THE SHORT-TAILED WEASEL IN UTAH AND COLORADO

At the time of publication of my "Bibliography of Utah Mammalogy" and its supplement (Proc. Utah Acad. Sci., Arts, and Letters, 13: 121–146, 1936, and Great Basin Nat., 2: 125–136, 1941) I had not been able to find an authentic record of the short-tailed weasel (*Mustela erminea*) from Utah, and the species seems to be somewhat rare throughout the intermountain West. Throughout many years of field work in the mountainous West I have never come in contact with this mammal until recent years, although we have assumed the presence of the animal in the area on the basis of reports from trappers and from the fact that it was recorded from the surrounding states.

On September 6, 1947, Mr. James Bee found a freshly killed adult male in the American Fork Cirque area on the north end of Mt. Timpanogos, Utah County, at an elevation of 8000 to 9000 feet. The animal had evidently been killed by a predator since the skull was badly crushed. The skin, however, was in good condition. The writer, while collecting pikas

on the east slope of Mt. Timpanogoa, shot an adult female on June 10, 1948. The animal had four active nipples, but the uterus contained no embryos. She was dragging a full grown *Microtus longicaudus* over loose sliderock on a very steep slope at an elevation of about 8000 feet. The time of capture was about 3:00 P.M. and the day was clear and bright. Unfortunately, the skull was rather badly damaged when the specimen was shot.

Later in the summer of 1948, while at the Rocky Mountain Biological Laboratory at Gothic, Gunnison County, Colorado, about eight miles north of Crested Butte, I had occasion to observe this species on several occasions. The species was collected in that same general area years ago by E. R. Warren. On July 17 I examined a specimen that had been shot by one of the students in rich undergrowth of an aspen forest at an elevation of 9500 feet. While trapping mice with Sherman live traps along a small mossy banked stream in deep conifer woods near camp, I captured an adult male on July 31. The animal was dead when I reached the trap, but the skin and skull were preserved in good condition. During the course of the summer we saw these small weasels on several occasions around a rock pile that had come from the foundation of an old hotel within fifty feet of our cabin. We judged this species to be almost as abundant as the larger *Mustela frenata* which was also common in that area.

All three of the collected specimens are in the Brigham Young University collection. They have not been critically studied for subspecific identification. The genital organs of some of the specimens were also saved for microscopic examination.—C. Lynn Hayward, *Department of Zoology, Brigham Young University, Provo, Utah. Received February 28, 1949.*

THE LEMMING VOLE, *SYNAPTOMYS BOREALIS*, IN NORTHERN MINNESOTA

Lemming voles of the subgenus *Mictomys* have never been recorded from north-central United States, although they might be expected to occur there judging from records of the species *Synaptomys* (*Mictomys*) *borealis* from southern Manitoba. Recently, examination of specimens in the collection of the Minnesota Museum of Natural History reveals that *Synaptomys borealis* does occur in north-central United States for we have found the following specimens referable to that species: one immature female (No. 951, MMNH) from Williams, Lake of the Woods County, Minnesota, collected by Gustav Swanson, August 5, 1932; one adult male (No. 2552, MMNH) from Warroad, Roseau County, Minnesota, collected by H. L. Gunderson and B. J. Hayward, July 27, 1948.

These specimens are probably referable to the subspecies *Synaptomys borealis smithi* Anderson and Rand, which has been assigned to specimens from southern Manitoba, although comparison of body and skull measurements with published measurements proved inconclusive.—Ralph M. Wetzel and Harvey L. Gunderson, *Museum of Natural History, University of Illinois, Urbana, Illinois, and Museum of Natural History, University of Minnesota, Minneapolis, Minnesota. Received February 7, 1949.*

RANGIFER CARIBOU IN MAINE IN 1946

Over a decade ago in this Journal (vol. 19, no. 1: 42, Feb., 1938) I stated that, except possibly for a single caribou reported in 1913, no Maine reports of occurrence of this species after 1910 were worth serious consideration. G. M. Allen (Extinct and Vanishing Mammals of the Western Hemisphere: 312, 1942), without giving details, advanced the date of last occurrence by stating that a small herd remained near the St. John River "until 1916, but since this time there seem to be no certain records." Anderson (Ann. Rept. 1938 Provancher Soc.: 94, 1939) clearly implied that caribou were absent from the Province of Quebec south of the St. Lawrence River, except in the interior of Gaspé Peninsula, and stated that the last ones in New Brunswick were reported there in 1927. Later (Nat. Mus. Canada, Bull. 102: 180, 1946), he stated that "possibly" small numbers existed in northwestern New Brunswick. More recently, Morris, in this Journal (vol. 29, no. 2: 173, May, 1948), stated that caribou no longer are found in the latter province. For the years since 1913 the only Maine report that I have found satisfactory on investigation is that here given—for a locality only about 180 miles from caribou country on the Gaspé.

In late August, 1946, Mr. and Mrs. Joseph Willette of Rumford, Maine, were driving in an auto along a new private road in Township 9, Range 18, in extreme northern Somerset County, Maine. This road connects with another running through a series of townships on the Province of Quebec side of the Maine-Canadian border and one must enter Maine here via Canada. The Willettes saw an animal in the road and drove up quite close to it. Mrs. Willette asked to have the auto stopped and, without getting out, she took a snapshot of the animal—a bull caribou with well-developed antlers. The Willettes were told by persons in the vicinity that this caribou had been seen over a short span of time at different localities on both sides of the International Boundary. The snapshot, which was shown to many interested persons, was quite a treasure and Mrs. Willette planned to present it to the State Library at Augusta. On July 5, 1948, she told me that, when cleaning house, she had discarded many photographic negatives—that of the caribou unfortunately included. Her letter of January 17, 1949, tells of the loss of the one print that she had: "I am sorry I cannot send you the caribou picture, as it is all mildewed." It was ruined with other belongings that were stored for the summer in a cellar while the Willettes were in the woods.—RALPH S. PALMER, *Department of Zoology, Vassar College, Poughkeepsie, New York.* *Received February 23, 1949.*

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(Conducted by Gerrit S. Miller, Jr., Remington Kellogg, and Emma M. Charters)

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TWENTY–NINTH ANNUAL MEETING

TWENTY-NINTH ANNUAL MEETING OF THE AMERICAN SOCIETY OF MAMMALOGISTS

The twenty-ninth annual meeting of the American Society of Manmmalogists was held in Washington, D. C., June 14–17, 1949. Meetings were held in the United States National Museum and headquarters were at the Hotel Washington. About 110 members were present as well as an additional number of guests.

The local committee on arrangements consisted of: H. H. T. Jackson, *Chairman*, M. C. Gardner, *Treasurer*, V. H. Cahalane, L. K. Couch, D. E. Davis, R. M. Gilmore, D. H. Johnson, W. M. Mann, C. C. Presnall, L. W. Swift, E. P. Walker, and Howard Zahniser.

PROGRAM

TUESDAY, JUNE 14

8:00 P.M.

Meeting of the Board of Directors, Hotel Washington

WEDNESDAY, JUNE 15

8:30 A.M.

Registration, Foyer, U.S. National Museum

10:00 A.M.

Auditorium, U. S. National Museum

Welcome by John E. Graf, *Assistant Secretary, Smithsonian Institution.*

Response by Tracy I. Storer on behalf of the *American Society of Mammalogists.*

1. The Division of Mammals of the U. S. National Museum. David H. Johnson, *U. S. National Museum.*
2. Mammal research in the Fish and Wildlife Service. Logan J. Bennett, *U. S. Fish and Wildlife Service.*
3. The International Union for the Protection of Nature—A new hope for vanishing species? Harold J. Coolidge, *Pacific Science Board, Washington.*
4. Present status of the great Indian rhinoceros. (Including film.) S. Dillon Ripley, *Yale Peabody Museum.*
5. Wildlife introduction in New Zealand. Clarence Cottam, *U. S. Fish and Wildlife Service,*

12:00 NOON

Group Photograph, South Steps, National Museum

2:00 P.M.

Auditorium, U. S. National Museum

6. An experimental study of habitat selection by the deermouse, *Peromyscus maniculatus.* Van T. Harris, *University of Michigan, Laboratory of Vertebrate Biology.*
7. Habitat relations of the woodmouse and the prairie deermouse. F. C. Evans, *University of Michigan, Laboratory of Vertebrate Biology.*
8. Growth and development in *Peromyscus leucopus noveboracensis. Arthur Svihla, University of Washington.*
9. A new type of cage for recording the total activity and daily rhythms of small mammals. Eskil L. Karlson, *University of Pittsburgh.*

10. Wheel-cage activity records of several species and subspecies of *Peromyscus*. Lee R. Dice and Sherman Hoslett, *University of Michigan, Laboratoty of Vertebrate Biology, and Luther College, Iowa*.
11. Laboratory studies with *Peromyscus*. Robert H. Stinson, *University of Toronto*.
12. Seasonal variation and home range in a wild house mouse population. Robert Zanes Brown, *Johns Hopkins University*.
13. Home ranges and populations of the western chipmunk, *Eutamias amoenus affinis* (Allen). Harold E. Broadbooks, *University of Michigan*.
14. A live-trapping plan for estimating population density of small mammals. Don W. Hayne, *Michigan State College*. (Read by L. R. Dice)
15. Small mammal succession in an Illinois stripmine. Ralph M. Wetzel. *University of Illinois*.
16. Home range of the Norway rat in a formalized environment. John B. Calhoun, *Johns Hopkins University*.

8:00 P.M.

Room 43, U. S. National Museum

Mammalogists' Rogues Gallery. William H. Burt

9:00 P.M.

Division of Mammals and Biological Surveys Laboratories

Get-together and Smoker

THURSDAY, JUNE 16

9:00 A.M.

Auditorium, U. S. National Museum

17. Some mammalian reservoirs of disease, with special reference to Malayan rodents. Robert Traub, *Army Medical Department*.
18. Subspeciation in the vole-lemmings of the subgenus *Synaptomys*. Ralph M. Wetzel, *University of Illinois*.
19. The use of cranial measurements in subspecies of *Thomomys talpoides*. C. A. Tryon, Jr., *University of Pittsburgh*.
20. Shrews from the Upper Pliocene of Kansas. Claude W. Hibbard, *University of Michigan*.
21. Food and feeding behavior of the opossum in New York state. W. J. Hamilton, Jr., *Cornell University*.

10:30 A.M.

Room 43, U. S. National Museum

Annual Business Meeting

(Members only)

Election of Officers

2:00 P.M.

Auditorium, U. S. National Museum

22. Studying and photographing small mammals. Ernest P. Walker, *National Zoological Park*.
23. Denning habits and home range of red foxes in New York state. William G. Sheldon, *University of Massachusetts*.
24. Timber wolf movements on Sibley Peninsula, Ontario. Antoon de Vos, *Ontario Department of Lands and Forests*. (Read by title only)

25. Cooperative wildlife management of the George Washington National Forest, Virginia. Ned Thornton and P. J. Hanlon, *Virginia Commission of Game and Inland Fisheries and U. S. Forest Service.*
26. Winter habits and numbers of the timber wolves. Wm. Rowan, *University of Alberta.* (Read by title only).
27. Notes on a tarsier born at the Philadelphia Zoo. Frederick A. Ulmer, *Zoological Society of Philadelphia.*
28. The fat content of polar bear tissues. Charles G. Wilber, *Woods Hole.* (Read by title only)
29. Fats in the tissues of the arctic walrus and seal. X. J. Musacchia and C. G. Wilber, *Woods Hole.* (Read by title only)
30. Fecundity of white-tailed deer. Ralph S. Palmer, *Vassar College.*

4:30 P.M.

A conducted tour of the National Zoological Park

7:00 P.M.

Annual Dinner

A picnic dinner at the Zoo Restaurant in the National Zoological Park, with a visit to the small mammal house after dusk for those who cared to make such a visit after the dinner.

FRIDAY, JUNE 17

9:00 A.M.

Auditorium, U. S. National Museum

31. Effects of mast failure on a raccoon population. Leonard M. Llewellyn, *Patuxent Research Refuge.*
32. "Expedition Moose." Randolph L. Peterson, *Royal Ontario Museum of Zoology.* (Sound film)
33. The autumn migration of the southern Yellowstone elk herd. Victor H. Cahalane, *National Park Service.*
34. Twin embryos and foetal membranes in the antelope, *Antilocapra americana.* C. A. Tryon, Jr., *University of Pittsburgh.*
35. An analysis of the big-game estimates of the United States, 1947. Neil W. Hosley, *U. S. Fish and Wildlife Service.*
36. Field studies of barren ground caribou in Keewatin. Francis Harper, *Mount Holly, New Jersey.* (Film)
37. An experimental census of whales in the Antarctic during Navy Operations "High Jump." Raymond M. Gilmore, *U. S. Fish and Wildlife Service.*
38. The first meeting of the International Whaling Commission, London, May, 1949. Hillary J. Deason, *U. S. Fish and Wildlife Service.*
39. The urgent whaling problem today. Harry R. Lillie, *Dundee, Scotland.* (Film)

2:00 P.M.

Room 43, U. S. National Museum

Final Business Meeting of the Society

(Members only)

Auditorium, U. S. National Museum

40. Some observations on the reproductive cycle of the pallid bat, *Antrozous pallidus.* Robert T. Orr, *California, Academy of Sciences*
41. The reproductive rate of commensal rats in Baltimore. David E. Davis, *Johns Hopkins University.*

42. Breeding habits of the southern woodchuck in Maryland. Roy A. Grizzell, Jr., *Patuxent Research Refuge*.
43. The sex reactions including the copulation of *Erethizon d. dorsatum*. Albert R. Shadle, *University of Buffalo*. (Film)
44. Methods and techniques for screening and field testing potential rat repellants. James R. DeWitt, Jack Welsh, and Irwin Bellack, *U. S. Fish and Wildlife Service*.

8:00 P.M.

Motion Pictures and Lectures

Auditorium, U. S. National Museum

Wildlife in the Arctic, by Allen J. Duvall

Wildlife in the Antarctic, by Carl P. Eklund

U. S. Fish and Wildlife Service

BUSINESS MEETINGS

At the meeting of the Board of Directors on June 14, positions were filled as follows: Lee Crandall was elected a trustee to fulfill the unexpired term (1948–1951) caused by the death of W. Reid Blair; William K. Gregory was reelected a trustee for the three year term 1949–1952; and William H. Burt was reelected editor.

The annual business meeting on June 16 was attended by 57 members and was presided over by Vice-President Storer, in the absence of President Kellogg. The following officers were elected: Tracy I. Storer, President; Lee R. Dice and William J. Hamilton, Jr., Vice-Presidents; Robert T. Orr, Recording Secretary; Donald F. Hoffmeister, Corresponding Secretary; and Viola S. Schantz, Treasurer. Directors for the term 1949–1951 were elected as follows: Emmett T. Hooper, David H. Johnson, Victor H. Cahalane, Stanley P. Young, and Harold J. Coolidge, Jr. The 161 nominees for membership were elected. The Society elected to join the International Union for the Protection of Nature and to continue as an affiliate of the American Institute of Biological Sciences.

It is with deep regret that the Society learned of the death of 20 members, three of whom were life (†) members and 6 of whom were charter (*) members: William C. Adams, †Edward P. Allis, Jr., †Courtenay Brandreth, Mitchel Carrol, James L. Chaworth-Musters, Leon J. Cole, Ned Dearborn, Reinhold L. Fricke, *Mabel P. Hollister, *R. Bruce Horsfall, George B. Lay, *Aldo Leopold, Einar Lönnberg, *E. L. Moseley, *Austin Roberts, Paul Rode, *William T. Shaw, Carl M. Steenberg, Harry H. Stone, †Francis B. White.

Two amendments to the By-Laws, as recommended by the Directors, were passed. Article II, Sec. 3, as now amended shall read, "Honorary members shall be elected by a majority vote of the Society upon unanimous recommendation of the Directors in recognition of distinguished service to mammalogy. They shall be exempt from all dues and shall be entitled to all privileges of members." Article VII, Sec. 2, was amended to read, "Any member upon payment of one hundred dollars at one time shall be entitled to life membership, and shall be exempt from membership dues."

The reports of the Recording Secretary, Corresponding Secretary, Treasurer, Trustees, and special committees on the Index and Check-list were read and accepted. Reports of the following standing committees were read and accepted: Conservation of Land Mammals, Bibliography, Marine Mammals, Economic Mammalogy, Nomenclature, Membership, Editorial. Reports of representatives to other societies were presented.

The site of the 1950 annual meeting was determined by preferential voting with the following results: 1, Yellowstone National Park; 2, Denver; 3, Charleston, S. C.; 4, Grand Canyon; 5, Rocky Mountain National Park; 6, Boston; 7, New York; 8, Columbus, Ohio; 9, Davis, California. The majority voted to have the meetings held in June.

The corresponding secretary submitted the following summary of membership, subscriptions, and mailing for the year ending December 31, 1948.

SUMMARY OF MEMBERSHIPS AND SUBSCRIPTIONS FOR 1947 AND 1948

	1947		*1948*	
Membership				
Changes since preceding annual report				
Nominees		125		161
Resignations	23		20	
Deaths reported	6		20	
Members dropped (delinquent)	18		26	
" " (previously inactive for duration)			42	
	—		—	
Total		47		108
		—		—
Net Change		+78		+53
Status as of December 31				
Honorary members	3		3	
Life members	51		50	
Members inactive for duration	48			
Annual members (excluding inactive for duration)	969		1071	
	—		—	
Total membership		1071		1124
Subscription				
Change since preceding report				
New subscriptions	59		81	
Subscriptions cancelled	41		20	
	—		—	
Net change		+18		+61
Status as of December 31				
Total paid subscriptions		309		370
Mailing List				
Total membership	1071		1124	
Members not receiving Journal	105		126	
	—		—	
Total members receiving Journal		966		998
Total paid subscriptions		309		370
		—		—
Total mailing list		1275		1368
Net change from preceding year		+102		+93

RESOLUTION

Be it resolved: That the American Society of Mammalogists at its twenty-ninth annual stated meeting extend to the United States National Museum and the National Zoological Park of the Smithsonian Institution, to the Fish and Wildlife Service and to the local committee its thanks and hearty appreciation for providing the facilities and entertainment which have contributed so largely to the success of the meetings and to the enjoyment of the attending members.

OBITUARY NOTICES

CHARLES TAYLOR VORHIES: 1879–1949

Professor Charles T. Vorhies, Charter Member of the Society, noted researcher on desert life, died May 10, 1949, while attending meetings of the Wildlife Society in Washington, D. C.

WILLIAM REID BLAIR: 1875–1949

Dr. W. Reid Blair, Trustee of the American Society of Mammalogists since 1933 and Emeritus Director of the New York Zoological Society since 1940, died May 1, 1949.

FRANK ERNEST ALOYSIUS THONE: 1891–1949

Dr. Frank Thone, science writer for Science Service since 1924, died suddenly in Washington, D. C., August 25, 1949. He was a member of the Society since 1932.

JOHN PEARCE: 1908–1949

John Pearce, Regional Director of the U. S. Fish and Wildlife Service, died April 8, 1949, after a long illness. Mr. Pearce joined the Society in 1931.

F. C. WALCOTT

Charter and Life Member of the Society, F. C. Walcott of Norfolk, Connecticut, died April 27, 1949.

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